# BIOMASS UTILIZATION STUDY

Roddickton-Main Brook Region, Nfld.

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## Roddickton-Main Brook Region, Nfld

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## EXECUTIVE SUMMARY

### Results

This study examined the technical and economic feasibility of using forest biomass to reduce the amount of diesel consumed for electrical generation within the boundaries of the White Bay Central Development area. The major findings were:

1. It is technically feasible at this pre-feasibility level to replace some of the diesel capacity at Roddickton with a woodchip/wood waste fired boiler and steam turbine.

2. The base case payback period is just over 16 years, taking into account fuel savings and additional labour and maintenance costs.

   All payback calculations are based on full capital costs being borne by the project. No allowance or consideration has been given to either Federal or Provincial grants or economic assistance.

   The base case analysis does not assign any capital charges to the diesel only system for diesel replacement. The sensitivity analysis indicates that taking these charges into account could reduce the payback period by about 2 years.

3. At this level of study, a unit of about 1250 kW appears optimal. It would have an annual wood consumption of just over 17,000 t in the first year of operation for a total wood cost of the order of $536,000. The estimated capital cost of the system is approximately $2,000,000.

4. The diesel generation systems at Main Brook and Croque are not large enough to warrant replacement with wood-fired units at this time. The fuel savings are not high enough to offset the capital costs.

5. Other systems, such as gasification and peat-fired boilers, have potential for the future but presently are not economic.

6. Forest Resources: The quantity of chips required for the 1250 kW unit ranges from 17000 tonnes/year in the first year to about 23000 tonnes/year at the end of the study period. A forest biomass inventory indicates that there is sufficient wood fuel available to meet these boiler requirements.

7. Socio-Economic Impact: The installation of a wood-chip burning boiler is expected to have a positive socio-economic impact on Roddickton. A considerable proportion of the fuel costs will remain in the community (paid to the wood chip suppliers), rather than being sent outside to the oil companies. Jobs will be created directly, in the supply of wood chips. Additional jobs will probably be created indirectly in the sawlog industry. At present, sawlog operations are not economical because there is no market for the lower quality wood (formerly sold as pulpwood). A market for the low quality material as woodchips would encourage the re-establishment of the sawlog industry.

**Implementation Plan**

The project shows sufficient technical and economic potential to warrant further study. The following implementation plan is therefore recommended.

1. Make a final selection of equipment. This involves discussions and close involvement with Newfoundland and Labrador Hydro on such work items as:

   a) Evaluate fire tube and water tube boilers in meeting system stability requirements, and choose the appropriate type.

   b) Finalize unit type and size. Consider the option of a steam engine as an alternative to a steam turbine.

   c) Evaluate technical aspects of combined chips/diesel system operation.

2. Obtain firm prices for supply and installation of all equipment.

3. Establish a harvesting plan, in conjunction with provincial forestry officials.

4. Obtain firm prices for fuel supply.

5. Obtain firm estimates of maintenance and personnel requirements based on existing wood fired generation systems e.g. in the United States and Europe.

After a complete study of the above, a final decision on the project can then be made on sound economic and technical grounds.

The anticipated schedule for activities required before start up is shown in Figure S1.

**Study Procedure**

The procedure used in this study and the major conclusions at each point in the study are described below.

- Electrical loads in the areas were analyzed.
- Alternative unit sizes were considered.
- A preliminary economic analysis determined whether or not the system warranted further consideration.

At this point, due to cost factors, Main Brook and Croque were set aside, and the detailed analysis concentrated on Roddickton. (Main Brook may have some potential in the future if it is interconnected with St. Anthony.)

Quotes were obtained and capital costs were estimated for suitable units for Roddickton. A unit size of 1250 kW was selected, considering savings, additional labour and maintenance and capital costs of new equipment. Selecting the size was a major work item, since it involved consideration of how each unit would be used in meeting the loads at various stages of load growth.

Several other work items were undertaken concurrently. Conclusions are as follows.

Peat: Sufficient deposits are available but production costs are too high to make peat competitive with wood chips for firing boilers at present. If a wood chip burning boiler is installed, it would be designed to burn peat as well, so that if and when peat becomes available on an experimental basis or at a reasonable cost, it can be used.

Gasification: Gasification is a promising technology. At present, however, gasifiers are too expensive and unreliable for use in this area.

Waste heat use: The use of waste heat from the boiler/turbine combination and from the cooling units of the diesel generators was considered. There are two possible uses at present,

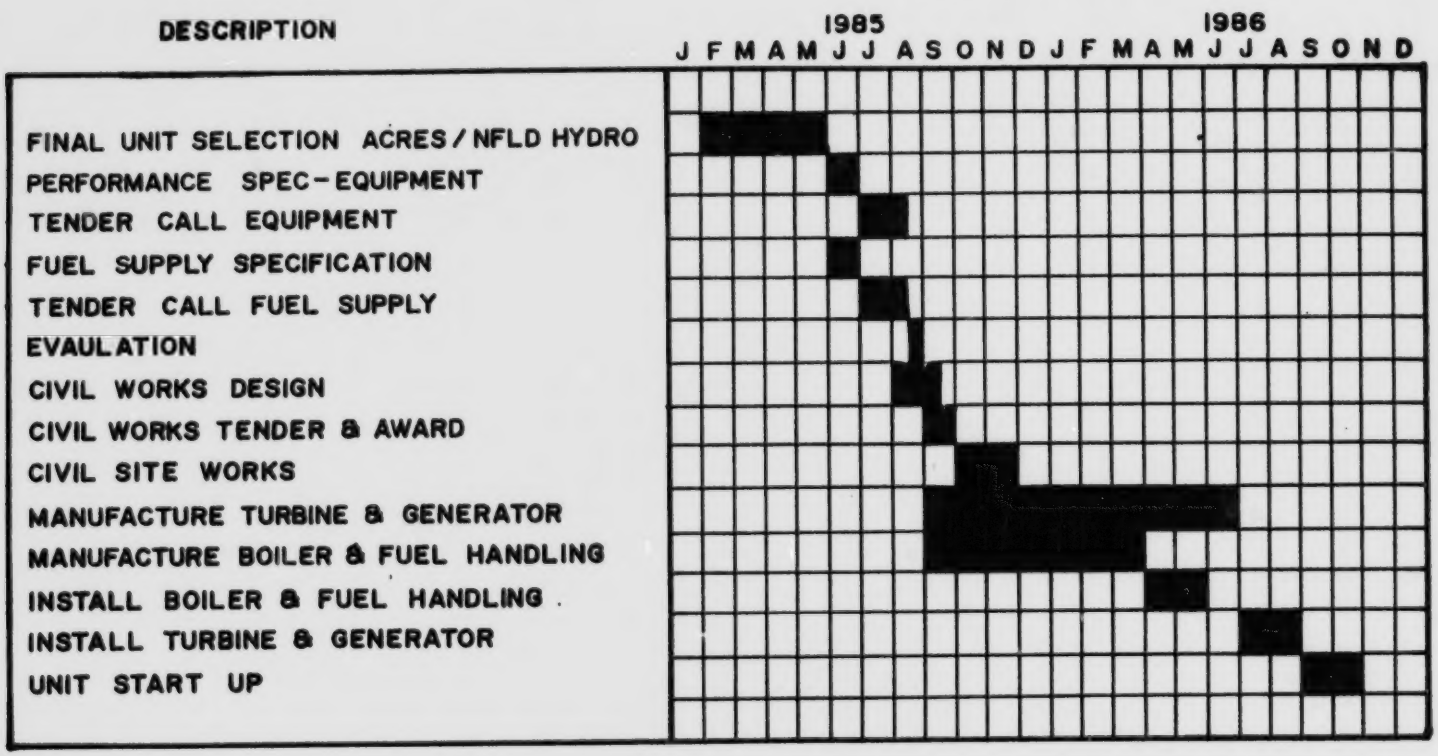
(1) to pre heat the wood chips to reduce the moisture content

(2) to provide district heating to two schools and a municipal building.

Due to potential layout and equipment problems in number (1) and the piping costs and reliability factor in number (2), no benefits were applied to the financial analysis from this source. However, in the event of implementation of the system, these factors should be reconsidered as they could have a positive impact on the system.

Forest inventory: A forest inventory was carried out, which showed that there are sufficient forest resources in the Roddickton Main Brook area to supply the long-term (20 years) requirements of a steam turbine generating plant.

Socio-economic analysis: A socio-economic analysis indicated that replacement of some of the diesel capacity at Roddickton with wood chips and sawmill residue will have a beneficial effect on the overall socio-economic situation of the region.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1986
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FINAL UNIT SELECTION ACRES / NFLD HYDRO
PERFORMANCE SPEC - EQUIPMENT
TENDER CALL EQUIPMENT
FUEL SUPPLY SPECIFICATION
TENDER CALL FUEL SUPPLY
EVAULATION
CIVIL WORKS DESIGN
CIVIL WORKS TENDER & AWARD
CIVIL SITE WORKS
MANUFACTURE TURBINE & GENERATOR
MANUFACTURE BOILER & FUEL HANDLING
INSTALL BOILER & FUEL HANDLING
INSTALL TURBINE & GENERATOR
UNIT START UP



FIG.S1

BIOMASS UTILIZATION STUDY
IMPLEMENTATION SCHEDULE

ACRES

# ÉTUDE DE L'UTILISATION DE LA BIOMASSE

## Région de Roddickton-Main Brook (Terre-Neuve)


### Résumé

La présente étude examine la faisabilité technique et la rentabilité de l'utilisation de la biomasse forestière pour réduire la quantité de carburant diesel servant à produire de l'électricité dans la région d'aménagement de la White Bay Central Development Association. Elle aboutit aux constatations principales qui suivent:

1. Il est techniquement faisable à ce stade préliminaire de l'étude, de remplacer une partie de la capacité diesel à Roddickton par une chaudière alimentée aux copeaux et aux déchets de bois et une turbine à vapeur.

2. L'analyse théorique du cas établie la période de recouvrement à un peu plus de seize années, si l'on considère les économies de combustible et les coûts additionnels en main-d'oeuvre et en entretien.

   Tous les calculs de recouvrement sont basés sur les coûts en capital applicables au projet; les subventions quelles soient du fédéral ou du provincial n'ont pas été prises en considération.

   L'analyse théorique du cas ne prend pas en considération les coûts de remplacement des diesels. L'analyse de sensibilité établit que si l'on tient compte de ces coûts la période de recouvrement pourrait être réduite à environ deux ans.

3. À ce point-ci de l'étude, une installation de 1 250 kW semble le meilleur choix. L'installation consommerait un peu plus de 17 000 t de bois, la première année d'exploitation et le coût total du combustible-bois serait de l'ordre de 536 000 $. Le coût en capital du système serait, selon les estimations, d'environ 2 millions de dollars.

4. Les systèmes de production d'électricité au diesel à Main Brook et à Croque n'ont pas une capacité suffisante pour justifier leur remplacement par des centrales alimentées au bois. Les économies de combustible seraient insuffisantes pour compenser les coûts en capital.

5. D'autres systèmes, telles la gazéification et des chaudières alimentées à la tourbe offrent des possibilités dans l'avenir, mais ne sont pas rentables actuellement.

6. Ressources forestières: La quantité de copeaux nécessaire pour alimenter une installation de 1 250 kW varie de 17 000 t par année, la première année, à environ 23 000 t par année, à la fin de l'étude. Un inventaire de la biomasse forestière a permis de constater qu'il y a suffisamment de combustible-bois pour assurer l'approvisionnement de la chaudière.

7. Impact socio-économique: On s'attend à ce que l'installation d'une chaudière alimentée aux copeaux de bois ait un impact socio-économique positif à Roddickton. Une part importante des coûts du combustible demeura dans la collectivité (soit aux fournisseurs de copeaux de bois), au lieu de revenir aux compagnies pétrolières de l'extérieur. Cela aura un impact direct sur la création d'emplois dans le secteur de l'approvisionnement de copeaux de bois. En outre, d'autres emplois seront probablement créés indirectement dans les scieries. À l'heure actuelle, les scieries ne sont pas rentables parce qu'il n'existe pas de débouchés pour le bois de qualité inférieure (vendu auparavant pour la fabrication de pâte à papier). La création d'un débouché pour le bois de qualité inférieure comme les copeaux de bois permettra aux scieries de connaître un nouvel essor.

Plan de mise en oeuvre

Le projet possède suffisamment de possibilités techniques et économiques pour justifier une étude approfondie. On recommande, par conséquent, le plan de mise en oeuvre suivant:

1. On recommande de faire un choix définitif concernant le matériel. Ce qui implique des entretiens et une étroite collaboration avec la Newfoundland et la Labrador Hydro sur des points comme:

   a) L'évaluation des chaudières à tubes de fumée et des chaudières aquatubulaires pour vérifier si elles satisfont aux exigences de stabilité du système afin de choisir le modèle approprié.

   b) La sélection définitive du modèle et de la capacité de l'installation. On recommande de considérer la possibilité d'opter pour un moteur à vapeur plutôt que pour une turbine à vapeur.

   c) L'évaluation des aspects techniques d'un système d'exploitation hybride diesel - copeaux de bois.

2. L'obtention d'offres fermes pour l'achat et l'installation de tout matériel.

3. L'établissement d'un plan de coupe, en collaboration avec les autorités provinciales du ministère des Terres et Forêts.

4. L'obtention d'offres fermes pour l'approvisionnement en combustible.

5. L'obtention d'estimations fermes concernant l'entretien et le personnel nécessaire déterminées à partir des systèmes de production d'électricité alimentés au bois employés aux États-Unis ou en Europe, par exemple.

Une fois que l'on aura terminé l'étude des points précédents, il sera possible de prendre sur des fondements économiques et techniques sains une décision finale concernant le projet.

Un calendrier anticipé où figurent les étapes du projet précédant sa mise en oeuvre apparaît au tableau S1.

Méthode utilisée par cette étude

La méthode utilisée par l'étude et les grandes conclusions de chaque étape de l'étude sont décrites ci-après:

- Analyse des charges électriques de la région.

- Examen d'installations de capacités différentes.

- Analyse économique préliminaire pour déterminer si le système justifie un examen plus détaillé.

En raison des coûts, les collectivités de Main Brook et Croque ont été éliminées de l'étude et l'analyse plus détaillée a porté sur Roddickton. (Main Brook peut offrir un potentiel dans l'avenir, en cas d'une interconnexion avec St. Anthony.)

On a obtenu des estimés des coûts en capital pour déterminer les installations qui seraient appropriées à Roddickton. L'installation de 1 250 kW a été retenue, après avoir considéré les économies, les coûts additionnels en main-d'oeuvre et en entretien ainsi que les coûts en capital du nouveau matériel. La sélection de la capacité de l'installation a constitué une étape de travail importante, car il a fallu examiner les différentes options d'utilisation de chaque installation en fonction d'une croissance graduelle de la charge.

D'autres travaux ont été menés simultanément. Les conclusions en sont les suivantes:

Tourbe: Des gisements suffisants sont disponibles, mais les coûts de production sont trop élevés pour que la tourbe soit compétitive avec les copeaux de bois en vue de l'alimentation des chaudières à l'heure actuelle. En cas de mise en place d'une chaudière alimentée aux copeaux de bois, l'installation serait étudiée pour brûler aussi de la tourbe, en prévision de la disponibilité de la tourbe soit à titre expérimental, soit à coût raisonnable.

Gazéification: La gazéification est une technique prometteuse, mais à l'heure actuelle les gazogènes sont trop coûteux et trop peu fiables pour le service dans la région étudiée.

Utilisation de la chaleur résiduelle: L'utilisation de la chaleur résiduelle du groupe chaudière/turbine et des circuits de refroidissement des génératrices alimentées au diesel a été examinée. Il existe maintenant deux possibilités:

1. le préchauffage des copeaux de bois pour réduire leur teneur en eau,

2. le chauffage à distance de deux écoles et d'un immeuble municipal.

Étant donné les problèmes éventuels découlant de l'implantation et des équipements dans le cas 1 et le coût des conduites et certains problèmes de fiabilité dans le cas 2, l'analyse financière ne tient pas compte des avantages qu'offriraient ces projets. En cas de mise en oeuvre du système, il conviendrait cependant de réexaminer ces deux projets susceptibles d'entraîner des effets positifs.

Inventaire forestier: Un inventaire forestier a permis de constater qu'il y a suffisamment de ressources forestières dans la région de Roddickton-Main Brook pour assurer l'approvisionnement à long terme (20 ans) de la centrale à turbine à vapeur.

Analyse socio-économique: Une analyse socio-économique indique que le remplacement d'une partie de la capacité diesel à Roddickton par une installation alimentée aux copeaux de bois et aux résidus des scieries aurait un effet bénéfique sur l'ensemble de la situation socio-économique de la région.

La présente étude a été préparée au profit de la White Bay Central Development Association par la firme Acres Consulting Services Limited, à l'aide du financement offert par les ministères Terre-Neuviens des Mines et de l'Énergie et des Forêts et des Terres et par le Programme de démonstration dans les collectivités éloignées mis sur pied par Énergie, Mines et Ressources Canada.

## 1.0 - INTRODUCTION

The purpose of this biomass utilization study was to investigate the technical and economic feasibility of using forest biomass to reduce the amount of petroleum-based fuels (diesel) currently used for electrical generation. The study was commissioned by the White Bay Central Development Association, and the communities considered were those served by the Association (Roddickton, Main Brook, Conche, Bide Arm, Englee and Croque). Funding was provided equally by the Province of Newfoundland and Labrador, Department of Forest Resources and Lands and the Department of Mines and Energy, and the Government of Canada, Energy Mines and Resources, under the CREDA Agreement.

## 2.0 - REVIEW OF CURRENT TECHNOLOGIES

### 2.1 - Conventional Steam Coupled with Steam Turbines

#### 2.1.01 - General Discussion

The use of conventional steam both high and low pressure is an accepted and time proven method to produce electricity using either single or multi-stage steam turbines. Package turbogenerator sets are available from a number of suppliers in a range of sizes from 50 to 10,000 kW. These units are completely self contained and when combined with a condenser and steam boiler make a compact operation.

#### 2.1.02 - Boiler and Fuel Handling Unit

Discussions on the boiler and fuel handling unit were held with Northfab Canada Limited, Volcano and KMW Limited. It was decided that the most economical unit to burn green wood fuel would be a three pass fire tube boiler with a moving grate retorte designed for wet fuel.

This unit can deliver steam to a turbine at 230 psig, 98% quality. The burning system would consist of a fire tube boiler using green wood chips as a source of fuel. The chips would be delivered to a receiving yard, dumped by means of a lift unloader into a hopper then transferred at high speed to a storage silo (SK-4). This high speed transfer would minimize problems with material freezing in the receiving hopper. The storage silo would be designed to hold 3-4 days supply under full load. This is enough fuel to ensure an adequate supply over holiday periods or in the event of mechanical breakdown equipment.

The fuel would be fed from the storage silo by means of a live bottom push rod system to a paddle conveyor then through a screening device to the stoker by means of a screw conveyor.

Recent discussions with senior personnel from the Northfab head office in Denmark indicate that excellent results in chip storage have now been obtained by dumping the chips on the floor of a receiving building and feeding the boiler with an overhead crane or loader. If the project proceeds, further investigation into this method of storage should be carried out.

### 2.1.03 - Turbogenerator Unit

Turbogenerator units with the capability of producing electricity from steam at 230 psig and 98% quality were reviewed. Four of the major suppliers of these units were contacted and after some discussions, it was decided that a package unit consisting of a multi-stage turbine unit, a synchronous generator and a condensing unit would be suitable for the system. If the project is taken to the feasibility level, a steam engine rather than a steam turbine should also be considered.

## 2.2 - Generation of Electricity from Wood Gasification

### 2.2.01 - The Gasification Process

In the early part of this century, gasification of fibrous materials, such as coconut shells, rice husks, cocoa husks and wood, was used to produce a flammable gas as a fuel for heating and providing mechanical power. In some cases, the end product was electric power.

Gasification of wood involves its thermal decomposition in the presence of water with a deficiency of combustion air to produce hydrogen, carbon monoxide and methane, mixed with nitrogen and carbon dioxide. The gas mixture was often used for power generation in reciprocating gas engines driving electric generators (Figure 2.1).

Wood gasifiers were eventually replaced in the mid-1920's by petroleum and natural gas as these two fuels became readily available at attractive prices. Nevertheless, some units have continued in operation to the present day. The drastic rise in the cost of hydrocarbon fuels over the last decade has stimulated a renewed interest in wood gasification and it has been the subject of much discussion over the past few years.

Compared with natural gas, which has a heat content of 1,000 BTU per cubic foot, gas produced from wood in an air-blown gasifier contains only 150-165 BTU per cubic foot. Hence, it is often referred to as "low BTU gas". This heat content can be increased by feeding oxygen to the gasifier in place of air, thus eliminating the nitrogen, or by blending the wood gas with natural gas.

A limiting consideration, particularly in downdraft gasifiers, is a requirement that the moisture in the fuel should not exceed a certain percentage of the total wood weight. This can be as low as 20 percent. Since the water content in green wood can be as high as 50 percent, pre-drying of the wood fuel may be necessary, using some of the produced gas as the drying agent. Slagging in the gasifier due to sand or earth contamination of the fuel wood can also be of concern. This is especially true when the fuel wood is from whole tree chipping.

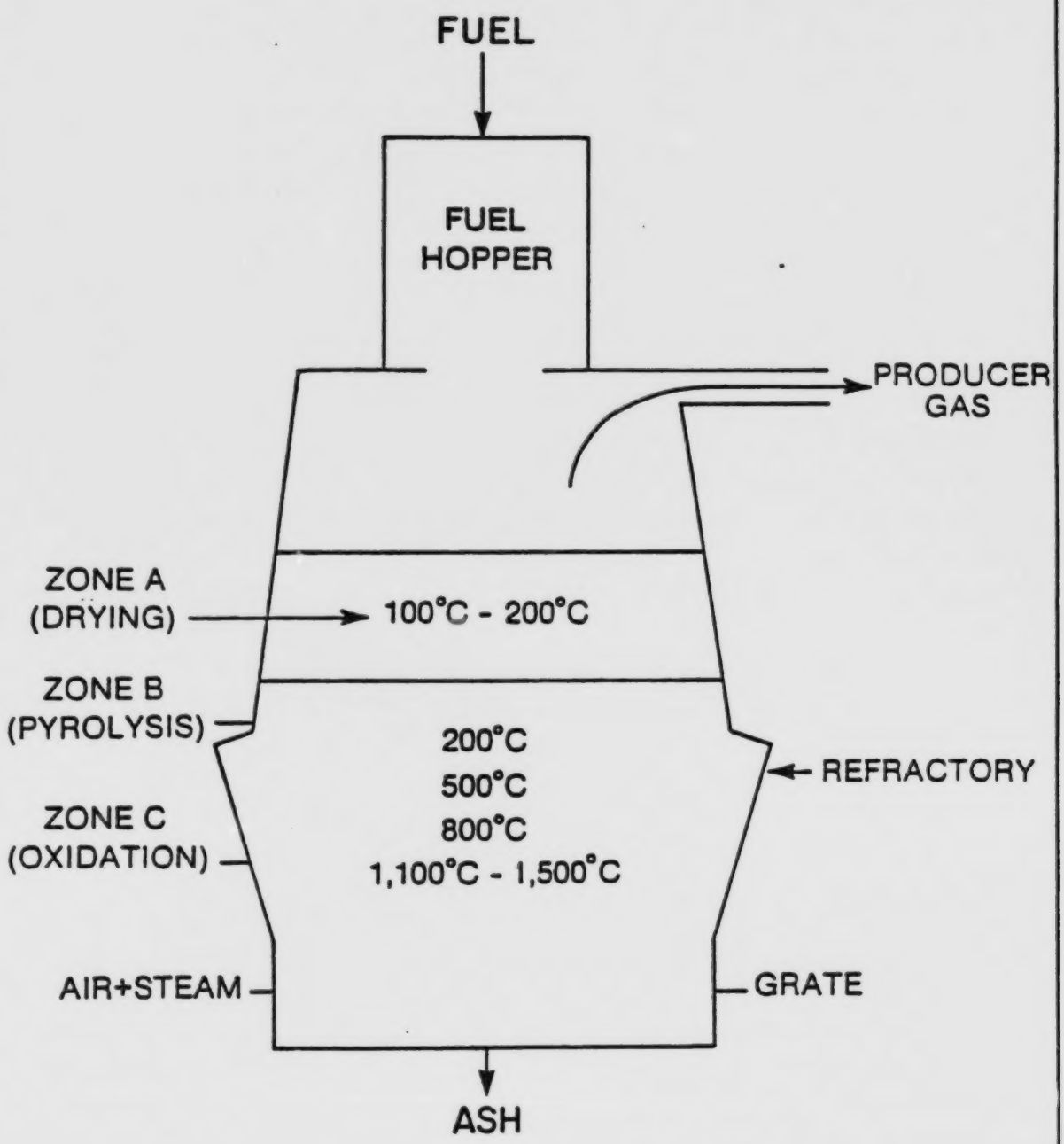



FIG. 2.1

ACRES

PRODUCTION OF WOOD GAS

The wood gasifying process takes place in three phases. First, the incoming fuel is dried and preheated to 100-200 $^{o}C$. Next, pyrolysis, which is heat absorbing, produces the components of the final product gas. Finally, there is oxidation of the char resulting from pyrolysis to ash. This is the heat producing reaction which provides the heat for pyrolysis and drying.

The product gas is passed through a gas washer which cools the gas and removes particulate and most of the tar carry-over. The final removal of tar may be incomplete although to a degree satisfactory for firing in a boiler. If the gas is to be used in gas engines or gas turbines, any tar carried over may cause problems by build-up on engine valve gear or turbine blades. The complete removal of tar is the subject of on-going research.

One of the earliest and most popular wood gasification units was the Crossley type which operated successfully throughout the world for many years. The gas produced was used for both direct combustion in furnaces and in internal combustion engines. These were built until the mid-1920's in capacities up to 600 horsepower (1.5 million BTU per hour).

To overcome the basic disadvantages of the fixed bed gasifier, more recent research and development work has been directed to the perfection of the fluidized bed gasification concept. The fluidized bed reaction time is much less than that for a fixed bed (currently less than one-sixth). Therefore, fluidized bed gasifiers are much smaller and cheaper for a given throughput. Alternatively, for a given size, output can be some six times greater than that of a fixed bed gasifier.

## 2.2.02 - Wood Gas Power Generation

Low BTU gas produced from wood is a potential fuel for use in diesel type engines or gas turbines. Diesel engines have operated on this type of gas in the past and there are today many gas turbines using gas with heat values as low as 80 BTU per cubic foot.

## 2.2.03 - Diesel Engines

During the early part of the century, producer gas was used to fuel many spark-ignition engines in sizes up to 600 HP (1.5 million BTU/h). The distinguishing characteristics of these engines was their physical size and slow speed, primarily due to large volume of gas fuel and its inherently low flame propagation velocity.

Recent studies have included investigations of the use of modern, higher speed and higher efficiency compression ignition diesel engines. The major drawback to using diesel engines would be the need to mix the fuel gas and combustion air thoroughly and meter the mixture to achieve the necessary degree of engine load control. Though the use of the weak gas in itself would not be detrimental to the engine efficiency, the high proportion of nitrogen in the fuel gas would reduce the engine capacity by about 40 percent compared with its capacity when using natural gas.

The older, reciprocating gas engines were designed for self-aspiration of the fuel gas, assisted by the relatively low pressure of the gas leaving the gasifier. Modern diesels generally require superchargers to force the combustion air into the cylinders to increase the capacity obtainable from a given piston-swept volume. To use wood producer gas as the engine fuel would necessitate an additional large

gas compressor to take care of the imcombustible nitrogen. It would be expensive and would absorb a large proportion of the engine output.

**2.2.04 - Gas Turbines**

In the earlier days of their development, the use of a low BTU gas as a gas turbine fuel was considered impractical. Recent developments, however, have shown the use of low BTU gas to be possible and Brown Boveri has place 20 gas turbines in operation, using blast furnace gas with heat values of 80-130 BTU per cubic foot.

Gas turbines have advantages in their relative simplicity and compact arrangement. However, this is offset by the need to compress gas to about 200 pounds per square inch before introducing it to the turbine combustion chambers. Cooling of the gas between compression stages might also be necessary to avoid creating a danger of hot gas explosion. This not only reduces the net output and efficiency of the gas turbine unit, but also adds considerably to its cost.

The application of gas turbines to a low BTU gas has been primarily in the steel-making industry where there are large quantities of blast furnace and coke oven gases which, if not used for power generation, could present a problem in their disposal. Though the use of wood producer gas has not been pursued actively, other low BTU gases such as from coal gasification, methane gas from sanitary fills and oil processing are being investigated by the major gas turbine manufacturers.

### 2.2.05 - Status of Wood Gasification Power

There are several prototype wood gasification power generating units in the USA, Canada and elsewhere. One 600 kW Imbert unit has been installed in Guyana in 1981 by Demerara Woods Limited. No information on its performance is yet available though slagging problems have been reported. In general, the generation of power from wood gasification is still in the development stage. It would not be prudent to introduce the technology at this time into an operation where satisfactory economic performance is of prime importance and where it is essential that a power plant offering proven reliability from the near term into the future be available.

The problems associated with wood gasification in the generation of electric power will no doubt be resolved in the foreseeable future. Notwithstanding, this probably will not be in time to suit the purposes of the Roddickton biomass project. Therefore, wood gas power generation is not considered a viable alternative to conventional steam turbine power generation at this time.

## 2.3 - Recommendations of System

### 2.3.01 - Review of Systems

A review of the two systems for producing electricity (i.e. steam turbines and wood gasification) was carried out. It is felt that due to the relatively new and developing technology of the wood gasification systems, the remoteness of the site from a center where technical assistance is readily available and the need for a reliable source of power generation this process should not be considered at present as an option for power generation.

Discussions with manufacturers of the steam turbine systems from both the steam supply and the generation sector assured us that this type of system could be installed in the Roddickton area and could operate with a minimum of maintenance and down time. In view of these factors, further work on the study was carried out on the assumption that power would be produced from burning green wood waste in a fire tube boiler capable of delivering steam at maximum 230 psig 98% quality to a turbogenerating set.

A water tube boiler would normally be considered for power generation. Due to high capital cost (3 times the fire tube unit at $1 million plus) and the limited savings due to increased efficiency in the range of unit considered it was decided to use the fire tube unit.

If the study is taken to the detailed feasibility level, however, the option of a water tube boiler should be reconsidered, since it may provide greater system stability. Manufacturers may also quote lower costs when firm prices are requested. A steam engine rather than a steam turbine should also be considered.

## 3.0 - REVIEW OF BIOMASS AVAILABLE

### 3.1 - Wood Chip and Sawmill Waste

A review of the study carried out by Northlands Associates (Section 8) indicates that there is sufficient biomass available.

This biomass would be in the form of sawmill waste and whole green chips both of which can be readily burned in the unit under consideration. The percentage of chips versus waste will have an effect on the pricing, since contractors will have the opportunity to quote a blended price.

## 3.2 - Peat Alternative

### 3.2.01 - Description of Peat Resources

The best information on the peat resources of the Northern Peninsula is found in the Peatland Inventory, Northern Newfoundland, 1981, prepared for the Department of Forest Resources and Lands by Northland Associates Limited. This report indicates that Newfoundland's Northern Peninsula, specifically the Roddickton area, is covered with scattered deposits of peat. Most of these deposits are either unsuitable in quality or insufficient in quantity to be harvested and utilized as a feasible fuel source.

Out of thirty designated deposits in the area, there are three major deposits near Roddickton. They probably contain sufficient quantities of peat to make production technically feasible. There are, however, problems in production which must be overcome before any major harvesting becomes worthwhile. For example, the peat deposits may be interspersed with outcroppings of mineral soil, which could make collection difficult and expensive. The heat content of the peat in this area has not been determined.

The thermal value of peat (BTU/lb) was taken from the Finland Energy Seminar (FES) proceedings, 1979 is in the range of 7950-9240 BTU/lb for dry peat (0% moisture content). This corresponds to a value of 8232 BTU/lb from the St. Shotts project and 9000 BTU/lb from the Peat Fuel Data Base report by R.F. Gosine, 1979.

**3.2.02 - Determination of Peat Requirements and Costs**

The quantity of peat required per year ranges from about 6000 tonnes/year to 15000 tonnes per year, depending on the unit size, BTU value and load year. Recent studies at the St. Shott's peat project indicate in Newfoundland that the BTU value for wood and peat is approximately the same. Therefore, if peat could be delivered to the site at the same cost as wood chips, it would be a viable alternative. At present there is not enough information available on peat production costs to determine true costs, but they may be expected to be higher in the initial years of a harvesting project.

Other factors besides cost which may complicate the use of peat as compared with wood chips include

- Material storage. Less storage space is required, but peat must be protected in winter. Once it is dried and stock piled it will not reabsorb much moisture, but the piles can freeze.

- Material handling. If the moisture content is too high, corrosion of equipment may occur. If it is too low, there is the danger of explosion.

- Reliability of supply. Due to the short drying season with variations in the amount of rainfall, it will be very difficult to be certain of the amount to be produced each season.

**3.2.03 - Conclusions**

The Roddickton area appears to have sufficient peat deposits to supply the Roddickton generating station. At this time, problems with peat production make it unlikely that the peat can be supplied at a cost low enough or in a volume reliable enough to make it competitive with woodchips. In the future if peat production costs are lowered, peat could serve as an additional fuel source.

As the boiler unit can burn peat as well as biomass, the installation could be used as a pilot plant for the development and testing of peat deposits in the area.

As per the terms of reference for this report, the main concern is in the area which shows the most potential for a demonstration project, i.e., the Roddickton area. Peat resources are also available in the Main Brook area and if any further consideration were given to a larger plant in Main Brook with possible interconnections to St. Anthony, an investigation into the burning of peat as a main fuel source or as a demonstration should be carried out.

## 3.3 - Study Fuel Costs

### 3.3.01 - Biomass Types and Study Cost

The mix of sawmill residue and whole tree chipping has a large influence on the cost of delivered fuel.

The wood fuel requirements based on present diesel/hydro/steam power mix are shown in Table A.1.

Examples of chip costs produced by whole tree chipping only are

| | $/Green Tonne |
|---|---|
| - Newfoundland Hardwoods Clarenville Results of public tender call for a 3 year supply. June 1984. | $ 33.50 |
| - Bonavista Peninsula Woodfuel Study Department Mines & Energy by Highlands Contracting November 1982 - $27.40. Escalation 10% added. | $ 30.14 |
| - Gander Hospital (Chipper provided). | $ 30.00 |
| - Fuelwood Study for Fishery Products Catalina Plant Department of Forest Resources and Lands. FPD-31. April 1984. | $ 41.50 |

Since sawmill waste will probably be available at a considerably lower cost, a contractor will have the opportunity to sell fuel at a reduced blended cost (e.g. 25% waste, 75% whole tree chips). For this study, therefore, a blended cost of $31.00 t will be used for woodchips, with sensitivities of $29 and $33/t.

It should be noted that at present a fuelwood supplier has to pay in the order of $4.40 per cord stumpage. This amounts to approximately $2.20 per green tonne. As the material being chipped is non commercial timber and the chipping operation will only enhance any silvculture operation, there are plans underway to try and have this cost waived for the production of wood chips. If this were so, the cost per tonne could be expected to drop to approximately $29.00 t.

Fuel costs are based on the assumption that an independent supplier would be contracted to provide wood fuel rather than a lumber mill. It is felt that the operation must be viable on its own and not be dependent on any other wood harvesting operation.

## 4.0 - ELECTRICAL LOADS AND POWER REQUIREMENTS FOR CROQUE/MAIN BROOK/RODDICKTON

### 4.1 - Electrical Requirements

#### 4.1.01 - Electrical Loads and Power Analysis

The objectives of the power and energy analysis were

1) to determine suitable unit sizes
2) to determine energy and resulting wood requirements for the various unit sizes.

The capital costs of the units were then compared with the expected fuel savings and the most economical unit was chosen.

Sections 4.1.03 to 4.1.05 describe the analysis for each community in turn. Section 4.1.02 below gives a general outline of the method of construction of the load-duration curves, which were used as the basis of the electrical analysis.

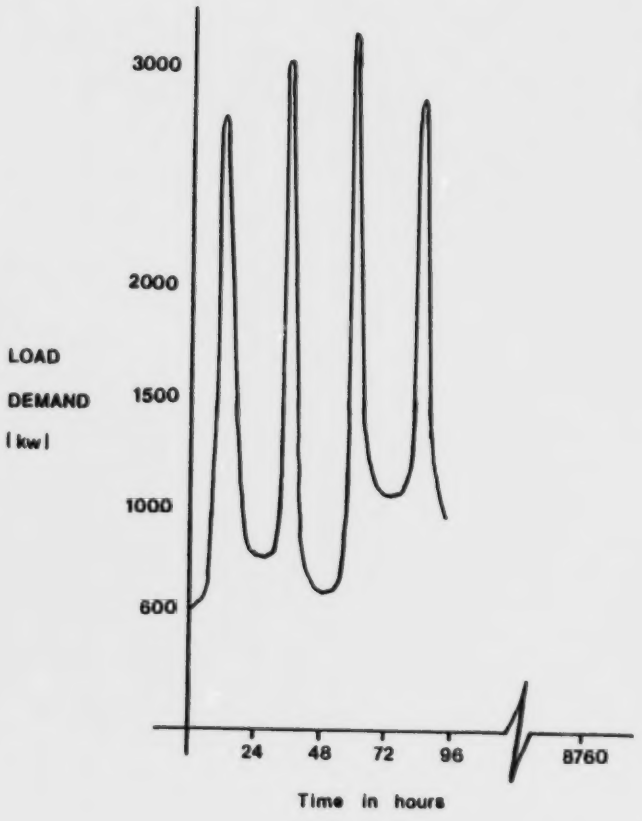
#### 4.1.02 - Load-Duration Curves

An electrical analysis is always concerned with 2 requirements, capacity (power), and energy. Load-duration (ld) curves are a method of representing both capacity (peak demand) and energy requirements. They may be prepared to cover any interval, but typically in energy planning studies they are prepared for each month.

Ideally, they are based on continuous data from the plants. A simple example is given in Figure 4.1. This example is for a community with a simple daily peak and daily minimum load. The number of hours the unit is operating at various capacities is tabulated. The cumulative values are then plotted. The

final plot is the ld curve. Generally it has a roughly triangular shape, with a sharp peak.

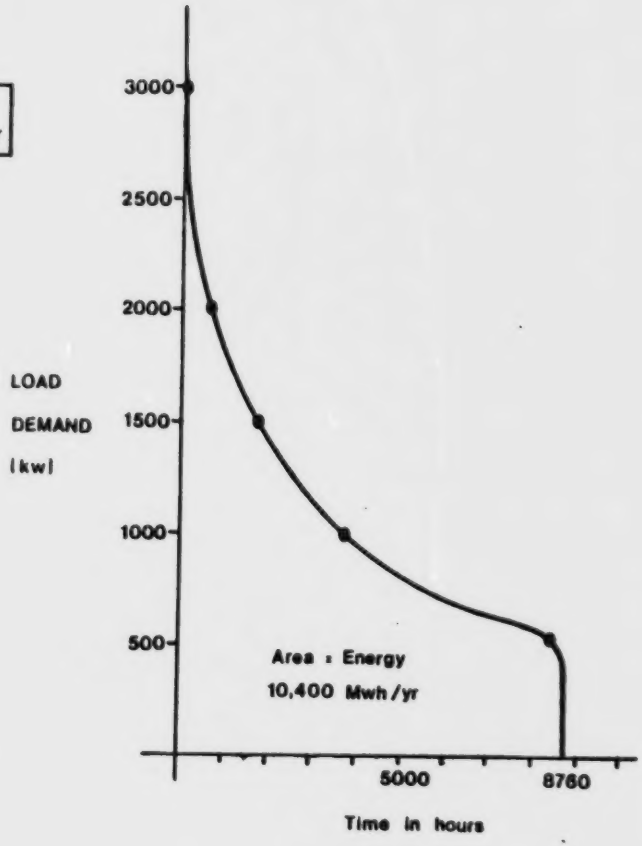
The benefit of using ld curves in energy planning is that the number of hours a unit will be operating in a given capacity range can easily be obtained, without analyzing daily record sheets or having to predict demand on a continuous basis. Another advantage is that for studies such as this, when such a detailed determination of the shape of the ld curves is not warranted, it is possible to construct a good approximation of the curves using known or predicted values of peak demand, total energy, and minimum load. This was the procedure used in this study.




(a) Continuous demand record (assuming peak demand at noon each day).

| Capacity | Number of hours per year |
|---|---|
| 600 | 8760 |
| 1000 | 6000 |
| 1500 | 2000 |
| 2000 | 800 |
| 3000 | 100 |

(b) Tabulation of demand from continuous record for year.




(c) Annual load-duration curve.

LOAD DURATION CURVES SCHEMATIC

BIOMASS UTILIZATION STUDY
WHITE BAY CENTRAL DEVELOPMENT ASSOCIATION

FIG. 4.1

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## 4.1.03 - Croque - Electrical Analysis/Preliminary Cost Review

The peak load demand and energy requirements for the community of Croque are given in Table 4.1.

**Table 4.1**
**Historical and Predicted Energy and Peak Load Demand, Croque**

| Year | Energy Demand (MWh) | Peak Load (kW) |
|---|---|---|
| 1980 | 176 | 57 |
| 1981 | 184 | 69 |
| 1982 | 214 | 72 |
| 1983 | 242 | 81 |
| 1984 | 276 | 98 |
| 1985 | 302 | 108 |
| 1986 | 313 | 112 |
| 1987 | 325 | 116 |
| 1988 | 338 | 121 |

(From NLH)

These needs are presently met with one 40 kW and 2 - 60 kW diesel generating units. Fuel consumption is as follows.

| | 1981 | 1982 | 1983 |
|---|---|---|---|
| Annual fuel use (litres) | 112 812 | 119 722 | 134 338 |
| Annual fuel cost | $ 29 221 | $35,831 | $43 238 |
| Cost per litre | $ 0.26 | $ 0.30 | $ 0.322 |
| Cost Increase | | 15% | 7% |

(From NLH)

It is difficult to obtain the minimum load since no records are kept at night. For this study, 18 kW was taken as a reasonable estimate of minimum load; it could conceivably be lower than this.

An annual ld curve was constructed using the annual peak of 81 kW, the estimated base load of 18 kW, and the known annual energy consumption of 242 000 kWh.

The 1988 annual ld curve was then predicted, using the same shape, and the predicted values of annual energy and peak demand from Table 4.1. It is given in Figure 4.2.

Unit size: From the ld curve, it can be seen that the range of unit sizes to meet the 1988 demand is from 30 kW to 125 kW. A 30 kW unit would be generally baseloaded, i.e. it would running flat out nearly all the time; a 125 kW unit would be run near full capacity about 2 percent of the time, and at about one quarter capacity about 40 percent of the time. The load would vary between the two extremes for the remainder of the time.

Preliminary Economic Analysis: A quick look at the costs and savings shows that installing a biomass unit in Croque is not economic. The capital costs are approximately as follows:

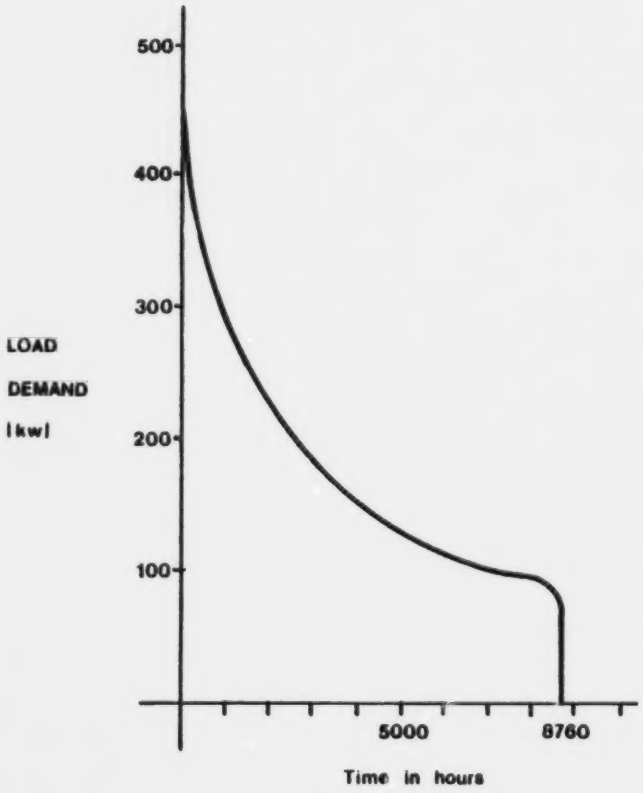
| | |
|---|---|
| Generating unit | $ 275,000. |
| Boiler, firebox | $ 300,000. |
| Cooling Tower | $ 50,000. |
| Condenser, civil works | $ 100,000. |
| Total | $ 725,000. |

The 1983 annual fuel cost was only $43,000. Even if this amount can be halved using biomass instead of diesel fuel (an optimistic assumption), the simple payback period is still over 40 years.

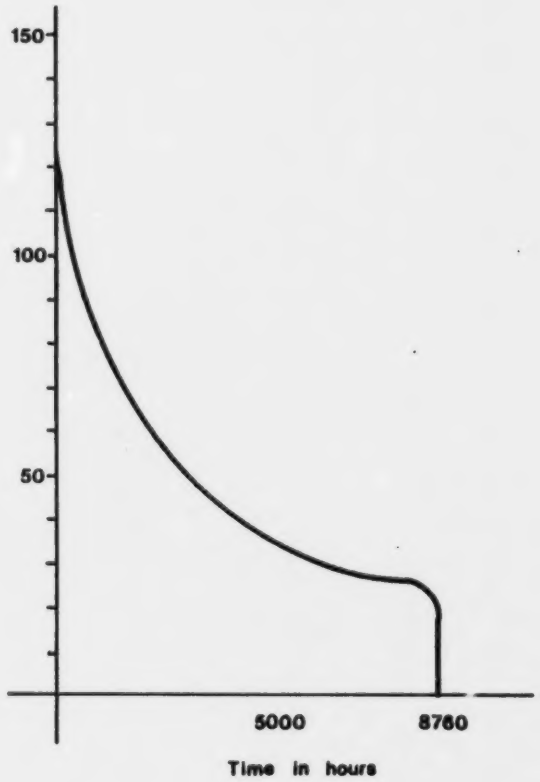
Because of the economic unattractiveness of the project, the analysis was not carried any further.

**4.1.04 - Main Brook - Electrical Analysis/Preliminary Cost Review**

A similar analysis was carried out for Main Brook. Table 4.2 gives the peak load demand and energy requirements. The ld curve for 1988 is presented in Figure 4.2.




MAIN BROOK




CROQUE

MAIN BROOK & CROQUE ESTIMATED 1988 LOAD DURATION CURVES

FIG.4.2

BIOMASS UTILIZATION STUDY

WHITE BAY CENTRAL DEVELOPMENT ASSOCIATION

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**Table 4.2**
**Historical and Predicted Energy and Peak Load Demand, Main Brook**

| Year | Energy Demand (MWh) | Peak Load (kW) |
|---|---|---|
| 1980 | 960 | 240 |
| 1981 | 993 | 252 |
| 1982 | 1054 | 336 |
| 1983 | 1079 | 336 |
| 1984 | 1127 | 357 |
| 1985 | 1182 | 375 |
| 1986 | 1241 | 394 |
| 1987 | 1301 | 413 |
| 1988 | 1364 | 433 |

(from NLH)

Main Brook is presently served by 5 diesel units, from 60 kW to 250 kW capacity. Historic diesel fuel consumption is as follows.

| | 1981 | 1982 | 1983 |
|---|---|---|---|
| Annual fuel use (litres) | 391 376 | 371 087 | 367 529 |
| Annual fuel cost | 102,828 | 108,984 | 114 698 |
| Cost per litre | 0.26 | 0.29 | 0.31 |
| Cost increase | | 12% | 7 1/2% |

Unit sizes: From the old curves for 1988, several unit sizes ranging from 100 to 440 kW were considered. The 100 kW unit would be baseloaded with diesel brought on as required. The 440 kW unit would supply all the energy but would be running on very low power (less than one quarter) nearly half the time.

Preliminary economic analysis: As for Croque, a preliminary analysis indicates that installing a biomass burning unit at Main Brook is not an attractive economic proposition. The capital cost is of the order of $900 000 (depending on the unit size chosen). The annual fuel cost (1983) is approximately $100,000.

Again, if as much as half of the fuel costs can be saved, the simple payback period is still over 16 years. The economic analysis was therefore not carried out any further.

One factor which could change the economic picture at Main Brook considerably is the possibility of an interconnection with St. Anthony. This is a complicated problem because of such factors as transmission line requirements and costs and would have to take into account NLH's plans for the whole area.

**4.1.05 - Roddickton - Electrical Analysis/Preliminary Cost Review**

A similar power and energy analysis was carried out for Roddickton. The expected energy requirements and the peak load demand for Roddickton are given in Table 4.3.

**Table 4.3**

**Historical and Predicted Energy and Peak Load Demand, Roddickton**

| Year | Energy Demand (MWh) | | | Peak Demand (kW) |
|---|---|---|---|---|
| | Diesel | Mini hydro | Total | |
| 1980 | 7124 | | | |
| 1981 | 5434 | | | |
| 1982 | 5842 | | | |
| 1983 | 6298 | 1300 | 7845 | 2026 |
| 1984 | 6545 | 1300 | 8122 | 2417 |
| 1985 | 7351 | 1300 | 8651 | 2568 |
| 1986 | 7832 | 1300 | 9132 | 2706 |
| 1987 | 8334 | 1300 | 9634 | 2849 |
| 1988 | 8864 | 1300 | 10164 | 3000 |

(from NLH update of RCDA report EMR Canada).

Roddickton is presently served by 5 diesel units ranging in size from 450 to 1000 kW, and one 400 kW Ossberger hydro unit. Total installed capacity is 3860 kW. Diesel fuel consumption is as follows.

| | 1981 | 1982 | 1983 |
|---|---|---|---|
| Annual fuel use (l) | 1 698 635 | 1898 684 | 2010 384 |
| Annual fuel cost | $441,645 | $559,421 | $628,053 |
| Cost per litre | $ 0.26 | $ 0.29 | $ 0.31 |
| Cost increase | | 12% | 7 1/2% |

(These figures from NLH, including station service).

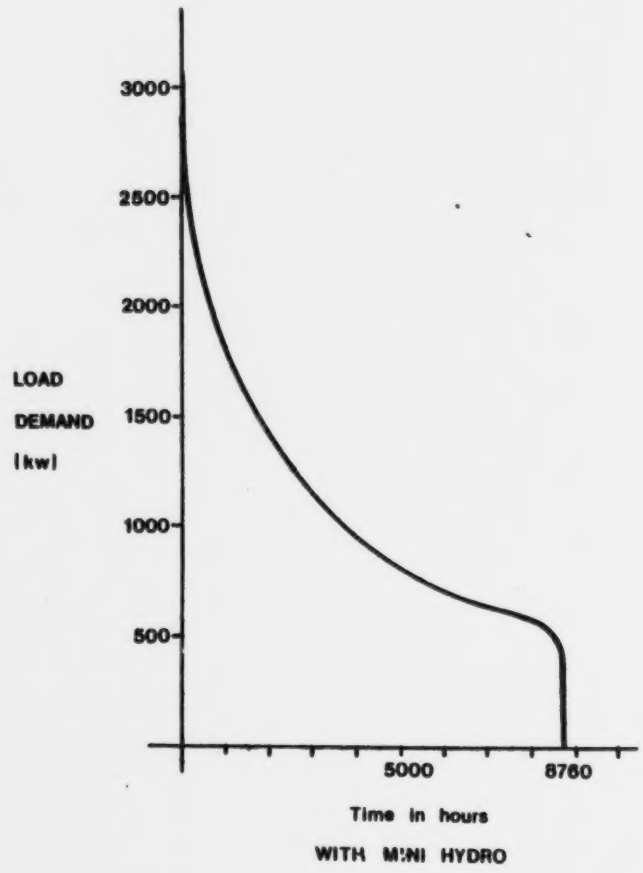
The diesel cost to May 1984 was $0.32/l.

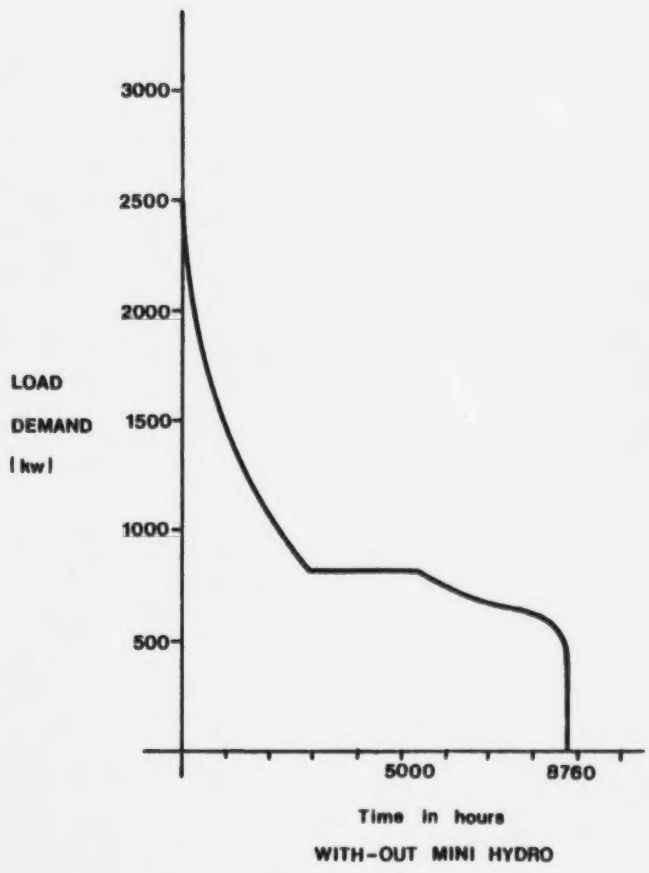
The estimated ld curve for 1988 is given in Figure 4.3, with one possible stacking location for mini-hydro shown.

Unit sizes: From the ld curve, it can be seen that the unit size required could range from a baseloaded 500 kW unit, to a 3000 kW unit to completely replace all the diesel generation.

Preliminary Economic Analysis: Capital costs are of the order of $1.5 M to $2.8 M. Fuel costs in Roddickton in 1983 were $628,053. If approximately 50% of the fuel costs can be reduced by using wood chips instead of diesel, the simple payback period could be of the order of 10 years, and the economics of the project look quite attractive.

A more detailed analysis was therefore warranted for the Roddickton plant.




RODDICKTON ESTIMATED 1988 LOAD DURATION CURVE

FIG.4.3

BIOMASS UTILIZATION STUDY

WHITE BAY CENTRAL DEVELOPMENT ASSOCIATION

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## 5.0 - GENERATOR SELECTION

### 5.1.01 - Roddickton: Selection of Unit Size

Having determined in the preliminary analysis that Roddickton looked promising, a detailed analysis was carried out. The first major task was to select the optimal unit size. This involved

- selecting a range of unit sizes for comparison
- estimating fuel and operating costs
- estimating capital costs
- calculating present worth for each alternative size
- selecting optimal size, based on minimum present worth.

With the unit size selected, further sensitivity analysis was done.

From the ld curve, four unit sizes were selected, 600 kW, 1250 kW, 1750 kW and 2500 kW. The costs for these were compared with a zero option, i.e. no replacement of diesel burning units.

A woodchip-burning system (rather than peat-burning) was assumed for this analysis. Section 3.2 discusses the use of peat as an alternative biomass fuel.

### 5.1.02 - Estimating Total Operating Fuel Costs

The total operating fuel costs were calculated for each option in the load years of 1983, 1988, and 1995 as described below, for each alternative size. Other years were then obtained by interpolation.

1. The number of hours each unit would be operating in a range of outputs was calculated using the estimated annual ld curve. This is important because a large unit operating at reduced capacity will be less efficient than a smaller unit running flat out.

2. The energy production of both biomass and diesel systems and the resulting steam requirements of the biomass system were calculated.

3. The wood chip consumption to produce the required steam was calculated. The detailed calculations for these first three items are given in Appendix A.

4. The total annual diesel costs required to supplement biomass units of various sizes were calculated.

5. The savings in each year for each unit size and the present worth of these savings were calculated.

The costs were based on the following assumptions.

1. A specific steam requirement of 3.38 lbs steam/lb chips at 75% of load was used taken from Newfoundland Hardwoods data. From August 25 to November 30, 1984, 2120 tonnes of chips produced nearly 17 million pounds of steam, a rate of 3.62 lbs steam/lb chips. The average moisture content was 42%. Adjusted to 45% moisture content, the rate is 3.38 lbs/lb.

   The Hardwoods unit was operating at an average of about 75% capacity. Boiler efficiency data from the manufacturer was used to adjust the consumption according to load.

2. Cost of diesel is $0.32/l in 1984, increasing at 5% per year. Cost of woodchips is $31.00/tonne, increasing by 3%/year.

3. One litre of diesel fuel produces 3.5 kWh of electricity.

4. Mini-hydro energy of 1300 kWh is subtracted from the total energy required. Some consideration was given as to how the hydro would be used, i.e. where it might be stacked in the ld curve. One possible location is shown for 1988 in Figure 4.3. A detailed consideration of how the mini-hydro might be stacked is not warranted for this level of study.

5. Power engineers, rather than diesel operators, will be required. Additional labour cost of $60,000/yr was assumed. Labour rates are assumed to rise at a rate of 3%/year.

6. The interest rate used for calculation is 13%.

7. It is assumed that the unit will be out for four weeks per year for maintenance.

8. Operating and maintenance costs on burning units moving parts was based on the manufacturers recommendation of 3% of the cost per year and for the generator turbine of 1% per year of the moving part costs. Maintenance costs in the first year are $8000, escalating at 3% per year.

**5.1.03 - Estimating Capital Costs**

The capital cost calculations are given in Table 6.1. The most expensive unit is the 2500 kW unit, at $2.84 M. There is a larger increase in capital costs from the 1250 kW to the 1750 kW unit because 2 boilers are necessary to produce the required steam for the larger sizes.

For the do-nothing and for the 600 kW unit options, capital charges are incurred when existing equipment requires replacement. An equivalent present worth was calculated and is given in Table

5.1. A 20 year life was assumed for all equipment. At this level of study, an evaluation of the effect on the generation expansion plan for each unit size was not considered. For the 600 kW unit, it was assumed that one of the 450 kW units would have to be replaced in 1995, plus one of the 1000 kW units in 1995, the other in 1998. For the do-nothing option, it was assumed that the 560 kW unit, the 2-450 kW units, and the 2-1000 kW units would all have to be replaced at various points during the study period.

The question of capacity credit, capacity reserve criteria, and salvage value of existing units must be addressed at a more detailed level of study. The approach described above was used simply for the purpose of choosing an approximate unit size.

**Table 5.1: Present Worth of Capital Costs Assumed Existing Diesel Generator Replacement**

| Interest Rate | Present Worth 600 kW | all diesel |
|---|---|---|
| 13% | $ 351 175 | $ 544 808 |
| 10% | 318 651 | 502 924 |
| 16% | 380 128 | 582 853 |

## 5.1.04 - Selecting Optimal Unit Size

To select the optimal unit size, the total present worth was considered over the 18 year study period.

From this analysis, it appears that the 1250 kW unit is the optimal size. Table 5.2 summarizes the present worths of all units for the base case. Sensitivities were carried out for the best and worst combinations of interest rate, fuel prices, labor costs, and capital costs. These best and worst cases along with the base case are plotted in Figure 5.1. The results show that a unit of about 1250 kW will be optimal in most circumstances.

However, a final decision on unit size and type will require examination with NLH of such questions as system stability and related technical considerations, and generation expansion planning.

**Table 5.2: Total Present Worth of Alternatives (million dollars)**

**Base Case:**

| Biomass Unit Size (kW) | 2500 | 1750 | 1250 | 600 | 0 |
|---|---|---|---|---|---|
| Savings | 1.67 | 2.21 | 2.15 | 1.05 | 0 |
| Capital Costs -Biomass Unit | 2.97 | 2.60 | 1.99 | 1.59 | 0 |
| -Diesel Replacement | 0 | 0 | 0 | 0.35 | 0.54 |
| Total | $ -1.3 | $-0.39 | $ 0.16 | $-0.89 | -$0.54 |

(Similar calculations were carried out for best and worst cases.)

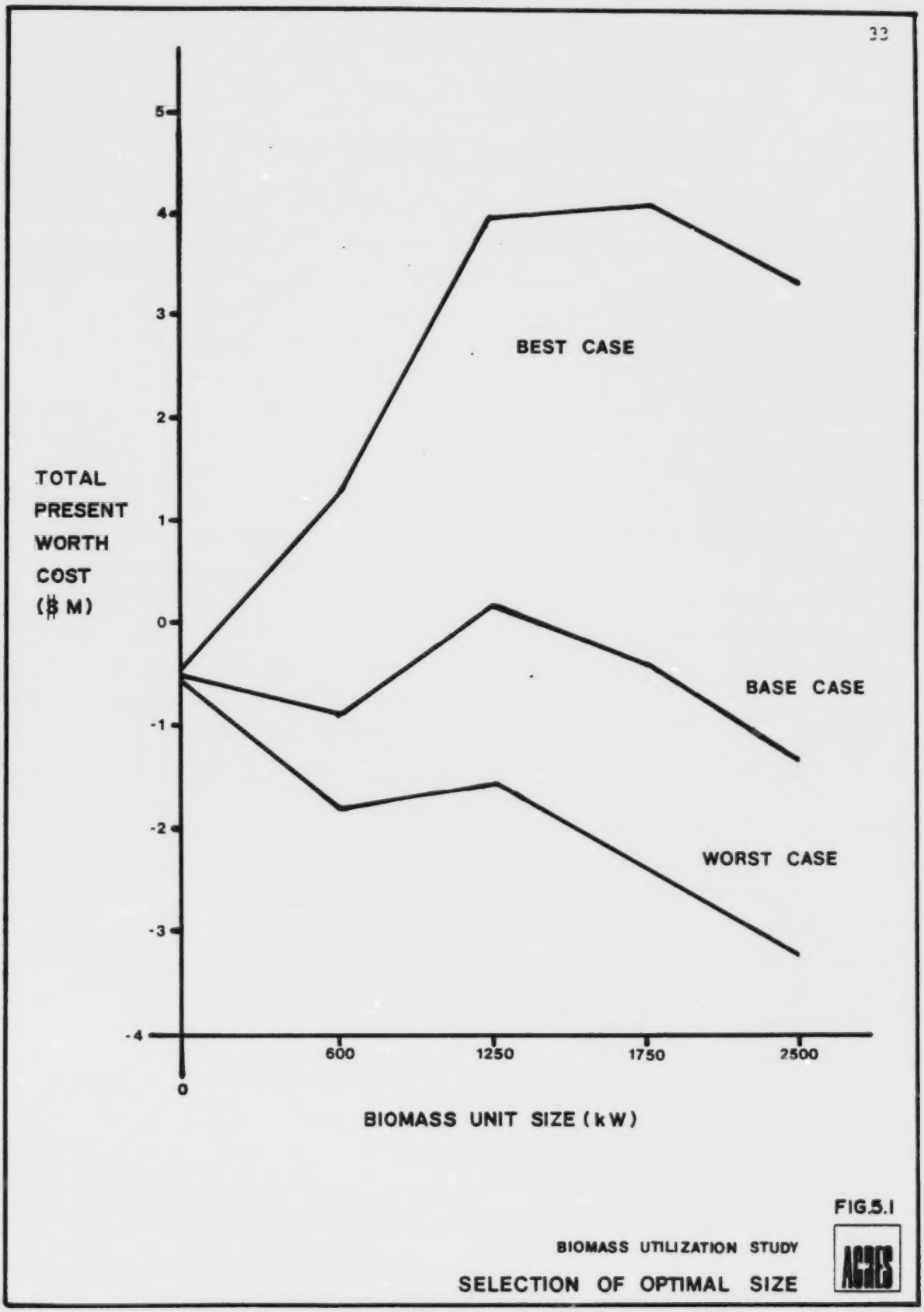


FIG.5.1

BIOMASS UTILIZATION STUDY

SELECTION OF OPTIMAL SIZE

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## 5.1.05 - Sensitivity Analysis: 1250 kW unit

Additional analysis was carried out on the 1250 kW unit to determine the sensitivity of the payback period and the present worth of the savings to changes in various economic considerations. These include changes to interest rates, fuel costs, labor costs, and capital cost. In addition, three special cases were considered.

The first case assumed that a steam engine rather than a steam turbine was used. Capital cost is slightly higher, but maintenance requirements are no more than for a standard diesel generator.

The second was the addition of capital charges for replacement of a diesel unit to the diesel only case. (The base case analysis assumed no capital charges for generator replacement during the study period.) For this sensitivity test, it was simply assumed that without the 1250 kW unit, one of the 1000 kW units would have to be replaced in 1995, at a present worth of $300,000. Replacement of the other diesel units is assumed to be common to both the diesel-only and the combined chips/diesel system.

The third case assumed a reduction of 40% in capital cost due to provincial and federal government assistance in an off-oil conversion.

The results of the sensitivity analysis are given in Table 5.3.

Assumptions of the base case are

a) Interest Rate - 13%
b) Woodchip Cost - $31/tonne, esc. 3%
c) Diesel Cost - 33¢/litre, esc. 5%
d) Additional Labor Cost - $60,000/yr, esc. 3%
e) Additional Maintenance Cost - $8000/yr esc. 3%

f) No funding from federal or provincial governments for off-oil conversion
g) No capital charges assigned to diesel-only system for generator replacement.

A complete computer run for the base case and summary economic tables for the sensitivity runs are given in Appendix A.

**5.1.06 - Comparison of Energy Cost**

The costs per kilowatt hour of energy for the diesel/chips system are compared with the diesel/only cost in Figure 5.2. The chip/diesel costs are lower throughout the study period.

Table 5.3

1250 kW Unit: Sensitivity Analysis

| Case | Present Worth of saving (million dollars) | Years to Pay back |
|---|---|---|
| Base | $ 2.15 | 16 1/2 |
| Factors Favoring Chips: | | |
| Low Interest (10%) | $ 2.85 | 13 1/2 |
| Low Chip Cost ($29) | $ 2.48 | 14 |
| High Diesel Rate (7%) | $ 3.51 | 11 1/2 |
| Low Labor Cost ($30,000) | $ 2.39 | 15 |
| Low Capital Cost Estimated (-15%) | $ 2.15 | 14 |
| Combination of Above (Best Case) | $ 5.64 | 8 |
| Factors Favoring Diesel: | | |
| High Interest (16%) | $ 1.66 | * |
| High Chip Cost ($33) | $ 1.82 | * |
| Low Diesel Rate (3%) | $ 1.03 | * |
| Combination of Above (Worst Case) | $ 0.44 | * |
| Other: | | |
| Steam Engine | $ 2.44 | 14 |
| New 1000 kW Diesel in 1995 | $ 2.46 | 15 |
| Lower Capital Cost (-40%) | $ 2.15 | 10 1/2 |

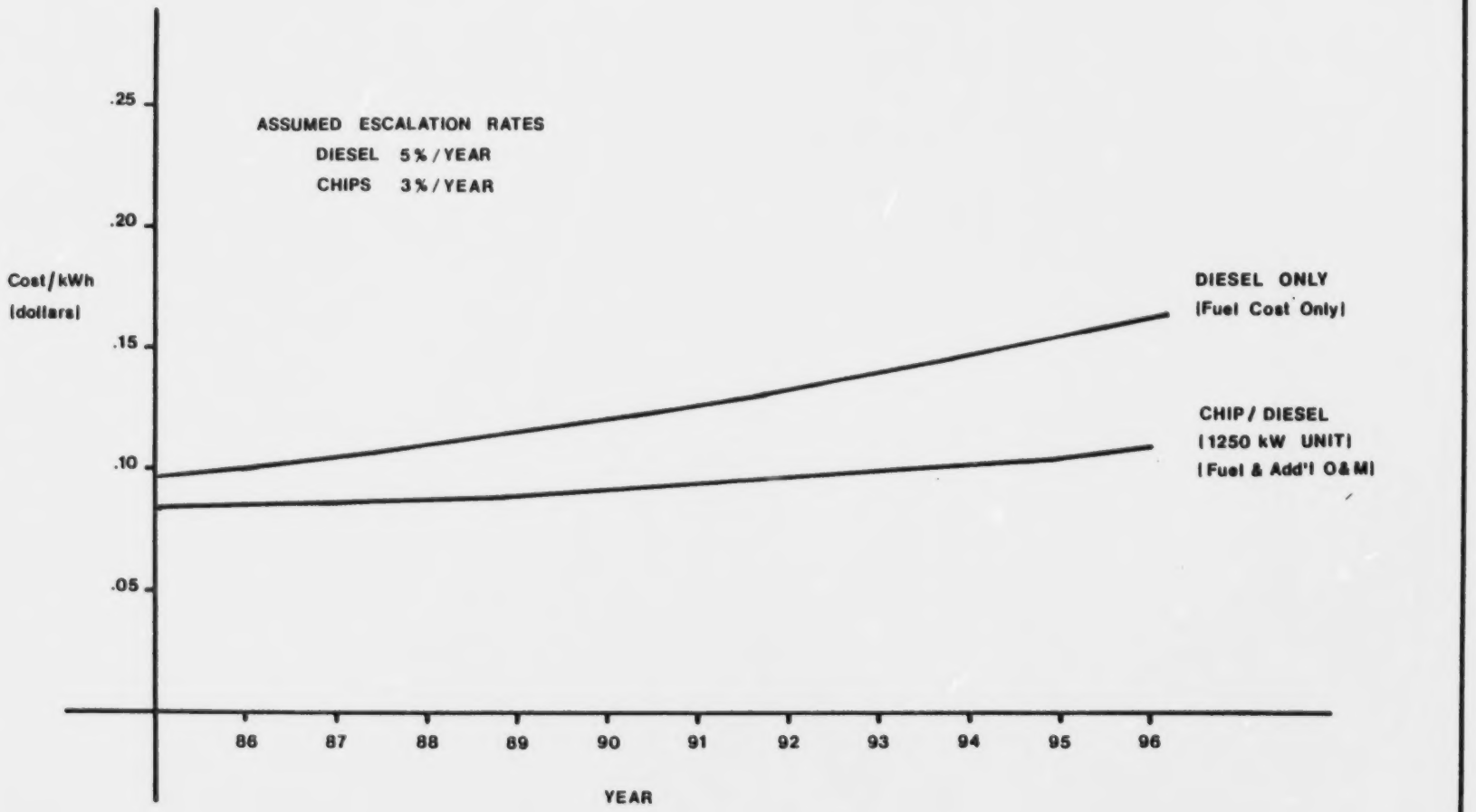



FIG. 5.2

BIOMASS UTILIZATION STUDY

COMPARISON OF COST/kWh

ACRES

## 6.0 - COST ESTIMATES, PLANS AND SPECIFICATIONS

### 6.1 - Procedure for Equipment Costs

#### 6.1.01 - General

To determine budget costs, the following steps were taken. The range of sizes for the generating units required was determined. The pressure and quality of steam available from the boiler were obtained from manufacturers information and given to the turbine manufacturer. The steam requirement in lbs/hr was then provided by the turbine manufacturers for various outputs.

The boiler manufacturers then provided prices for units having the required steam output.

#### 6.1.02 - Turbo Generator Requirements and Costs

After a review of the load requirement for the three areas, Croque, Main Brook and Roddickton, a number of companies which supply turbo generating equipment were contacted and asked to provide budget prices and steam requirement at various loads. Due to the amount of work for the manufacturer, this was a very time consuming process. Three estimates were received as shown in Appendix A.

The Trane-Murray (Affiliated Engineering) price of $368,000 was used for estimating purposes.

The U.S. rate was increased by a factor of 1.60 to allow for duty, currency, exchange, freight and customs.

In summary, the unit selected for the purposes of budgeting was a Coppus Murray Turbine with a three phase sixty cycle synchronous generator with voltage regulator including a Woodward oil relay governor with motor operated synchronizing device, including all controls. A more detailed specification is included in Appendix B and C.

The associated condensing unit cost was provided by Trane-Murray.

The cooling tower requirements were met by using a Marley Model 452-202 unit. See Table 6.1.

**6.1.03 - Boiler Requirements and Costs**

Based on the maximum steam requirements of 230 psig at 98% quality to be delivered to the turbine, quotations were obtained from Northfab Canada Limited to supply and install a complete package of boiler and fuel storage to meet this requirement. As Northfab Canada Limited is now supplying two wood burning units for projects by Acres in Newfoundland and budget quotations were received on a similar size unit on which Northfab was low in all cases, it was not felt necessary at this stage to request further price confirmation. The Northfab burning system (with moving grates) is particularly well suited to this application.

If the project proceeds further, firm prices should be requested from all suppliers of these units.

The boiler unit selected for budget purposes was a three pass fire tube unit with a moving grate retort capable of burning greenwood fuel. The unit would be fed by a screw type stoker and be completely automatic. All necessary safety devices would be included. An oil burning attachment could be provided to ensure a steam supply in the event of a problem with wood chip supply or feed.

A firetube boiler was selected because it is more economical. Before a final decision is made, however, further study is required to ensure that a fire tube unit can meet the system stability criteria.

It is also possible that better prices will be obtained from manufacturers when firm quotes are requested.

The fuel would be received into a storage silo capable of 4 day storage under full load. The silo would be equipped with a live bottom push rod system which will transfer the fuel via screen/shredder to the furnace unit (Appendix E 7150-SK-2).

Photographs 1 and 2 in Appendix D show a similar system recently installed at the Newfoundland Hardwoods plant in Clarenville.

Budget prices received from Northfab are included in Appendix B. The price used for budget purposes on the 1250 kW unit was $483,000. See Table 6.1.

**6.1.04 - Fuel Unloading System**

Due to the severe winter conditions experienced in the Roddickton area, it is desirable to move the fuel from the transport rack to the storage silo in the least possible time to prevent material and equipment freezeup.

After discussion with equipment suppliers and end users, it was felt that a system capable of dumping a tractor trailer or truck onto a high capacity conveyor which would then transfer the fuel to a silo would be best. The fuel would not be screened before transfer into the silo but would go through a low capacity screen between the silo and boiler. See Appendix E SK-2.

Morbark was contacted on the supply of a system to perform this task. Budget prices were received for a total estimated cost of $104,000. This unit has the advantage of being able to handle both single and tandem axle trucks. With this system, the source of supply and method of delivery is not limited due to equipment.

Photographs 3, 4, 5, and 6 in Appendix D show a similar system in operation at the Abitibi Price yard in Grand Falls.

**Table 6.1**
**Capital Costs, Biomass Units**
**(1983 Canadian Dollars)**

| Item | Unit size (kW) | | | |
|---|---|---|---|---|
| | 600 | 1250 | 1750 | 2500 |
| *Turbine(1) | $ 342 000 | $ 368 000 | $ 454 000 | $ 548 000 |
| *Condenser | 88 000 | 115 000 | 142 000 | 173 000 |
| *Cooling Tower | 70 000 | 125 000 | 175 000 | 200 000 |
| Boiler & mat'l storage | 392,000 | 483 000 | 652 000 | 745 000 |
| *Mat'l handling | 104 000 | 104 000 | 150 000 | 150 000 |
| Civil Works | 100 000 | 168 000 | 210 000 | 210 000 |
| Elec. & Mech. | 50,000 | 80 000 | 100 000 | 120 000 |
| Sub Total | 1 146 000 | 1 443 000 | 1 883 000 | 2 146 000 |
| Contingency 15% | 172 000 | 216 000 | 282 000 | 322 000 |
| Engineering 15% | 197 000 | 249 000 | 325 000 | 370 000 |
| Sub Total | 1 515 000 | 1 908 000 | 2 490 000 | 2 838 000 |
| FST | nil | nil | nil | nil |
| RST 12% | 72 500 | 85 500 | 110 500 | 128 500 |
| Total | 1 587 500 | 1 993 500 | 2 600 500 | 2 966 600 |

(1) U.S. Price 1.6 to include duty exchange rate, freight, customs.

*subject to 12% RST
FST not applicable.

## 6.2 - Site Costs

### 6.2.01 - Civil Works

The Roddickton site as shown in photograph #10 and 11 is relatively level and no major problems are anticipated. The work required under this section would include boiler and generator room building, concrete foundations, silo pad material receiving pad and cooling tower base.

This portion of the work could be performed by local contractors to ensure higher benefits to the area.

### 6.2.02 - Electrical and Mechanical

All electrical and mechanical work other than the tie in to the existing system would be carried out by the generator contractor or the boiler supplier. A sum of $80,000 has been allocated for this work.

An electrical schematic hook up to the existing system is shown in Figure 6.1.

Cost estimates are shown in Table (6.1).

### 6.2.03 - Operating Costs

The introduction of a steam unit will require a change in operator qualification with a corresponding increase in operating costs. These costs have been included in the economic calculations.

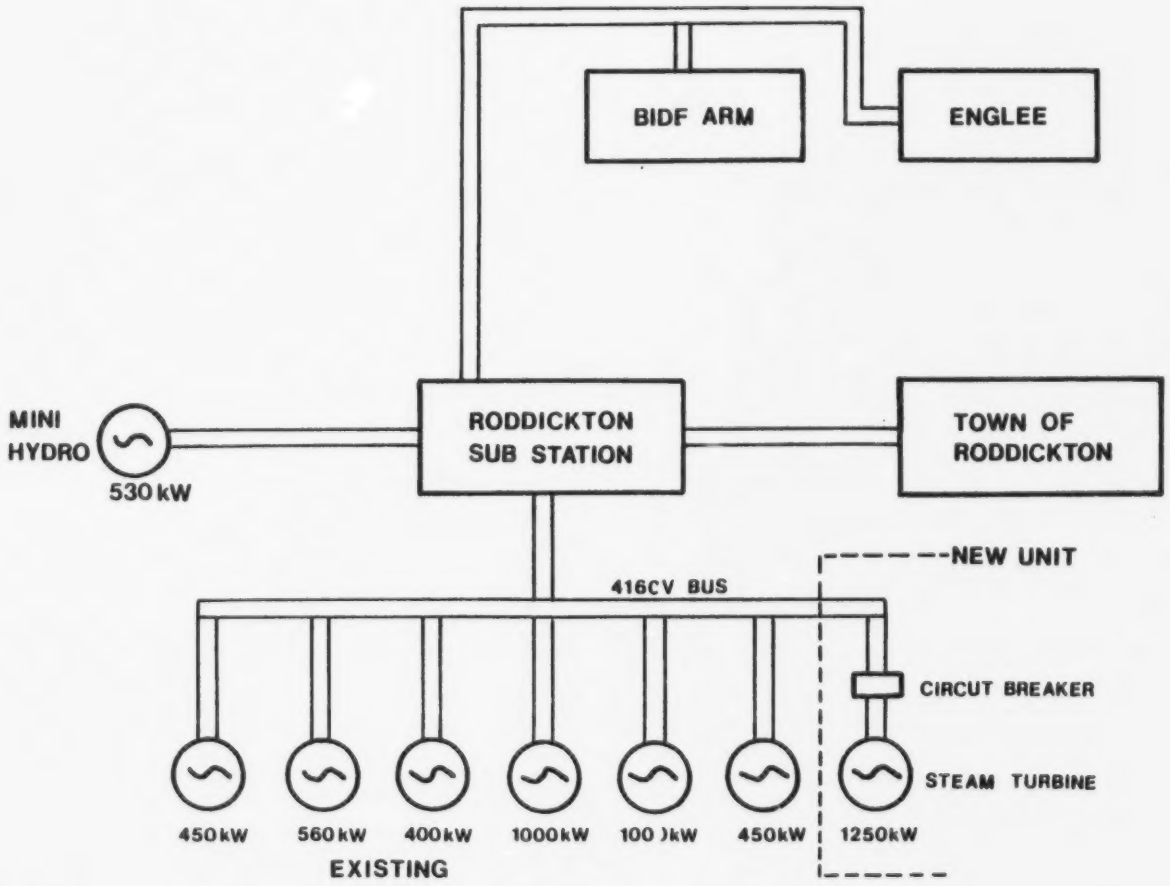



FIG.6.1

RODDICKTON TIE IN

**6.2.04 - FST, RST and Corporate Taxes**

Present indications are that the wood burning equipment is not subject to federal sales tax (FST) or retail sales tax (RST). However, this is somewhat dependent on the method of tender in the case of RST.

Discussion with Mr. Pike of the federal Tax Department indicates that the complete generating system will not be subject to any tax. This would have to be confirmed at a later stage in the study. (At present, K. Thompson is responsible for such confirmation).

Mr. G. Taylor of the provincial Tax Department advised that a 12% RST would be applicable on the generating and material handling equipment. This has been included in the capital cost estimate. Indications are that some changes in the provincial RST are in progress and this would be reviewed if the project proceeds.

## 7.0 - PROVINCIAL AUTHORITIES AND INSURANCE

### 7.1 - Provincial Fire Commission Requirements

Discussions were held with Mr. J. Cardolis, the Provincial Fire Commissioner and Mr. W. Drover, P. Eng. of the Fire Commissioner's office. It was noted that approval would be dependent on final drawings; however, as the unit is similar to other approved installations, with a sprinkler arrangement and an air lock in the fuel supply system, and the fuel storage silo remote from the boiler room, they could see no major problems with approval.

The specification for the fuel supply would contain a clause covering the exclusion of any material containing a product such as stove oil, diesel oil, linseed oil or any other contaminate which could cause spontaneous heating or liberate flammable or combustible vapours.

### 7.2 - Environmental Requirements

All stack emissions will meet the requirements of the Newfoundland Department of Environment Air Pollution Control Regulations 26/81. It was noted that the wood burning units of the type investigated have no adverse effect on the environment. Tests carried out on a boiler with a similar combustion process at the Bell Industry Plant in Seafort Ontario burning spruce green whole tree chips gave a $CO_2$ level of 14% and a smoke level of #1 - #3.

All fly ash will be completely removed from the stack emissions by a cyclone separator.

## 7.3 - Insurance

Experience from two previous installations and discussion during other studies with various insurance groups indicate that by using the equipment as indicated in this study with the built in safety devices there would be no change in insurance premiums. This would be subject to a review of final plan by the owner's insurance company.

## 8.0 - FOREST RESOURCE (NORTHLAND ASSOCIATES LIMITED)

The Roddickton/Main Brook region falls within the Department of Forest Resources and Lands' Forest Management Unit 18 (Figure 8.1). Forested lands within this region are controlled from the Forest Management Office in Roddickton.

The unit contains a total of 387,639 ha of land. This area is broken down into 101,164 ha of non-forested land; 154,553 ha of scrub forest; 131,922 ha of productive forest land.

Cutting rights for all forested land in the unit are controlled by the Crown. Bowater has large acreages of private and leased land in the unit but the cutting rights to these lands were passed over to the Crown by Bowater.

The age class distribution for the productive forest land in the unit is as shown in Table 8.1. This table indicates that a large percentage (54%) of the productive forest land area falls in the overmature age class (81+). On a volume basis 83% or 8,830,503 $m^3$ of the gross merchantable volume falls in the overmature age class. Table 8.2 gives a breakdown of merchantable volume by working group for the mature (41-80) and overmature (81+) age classes.

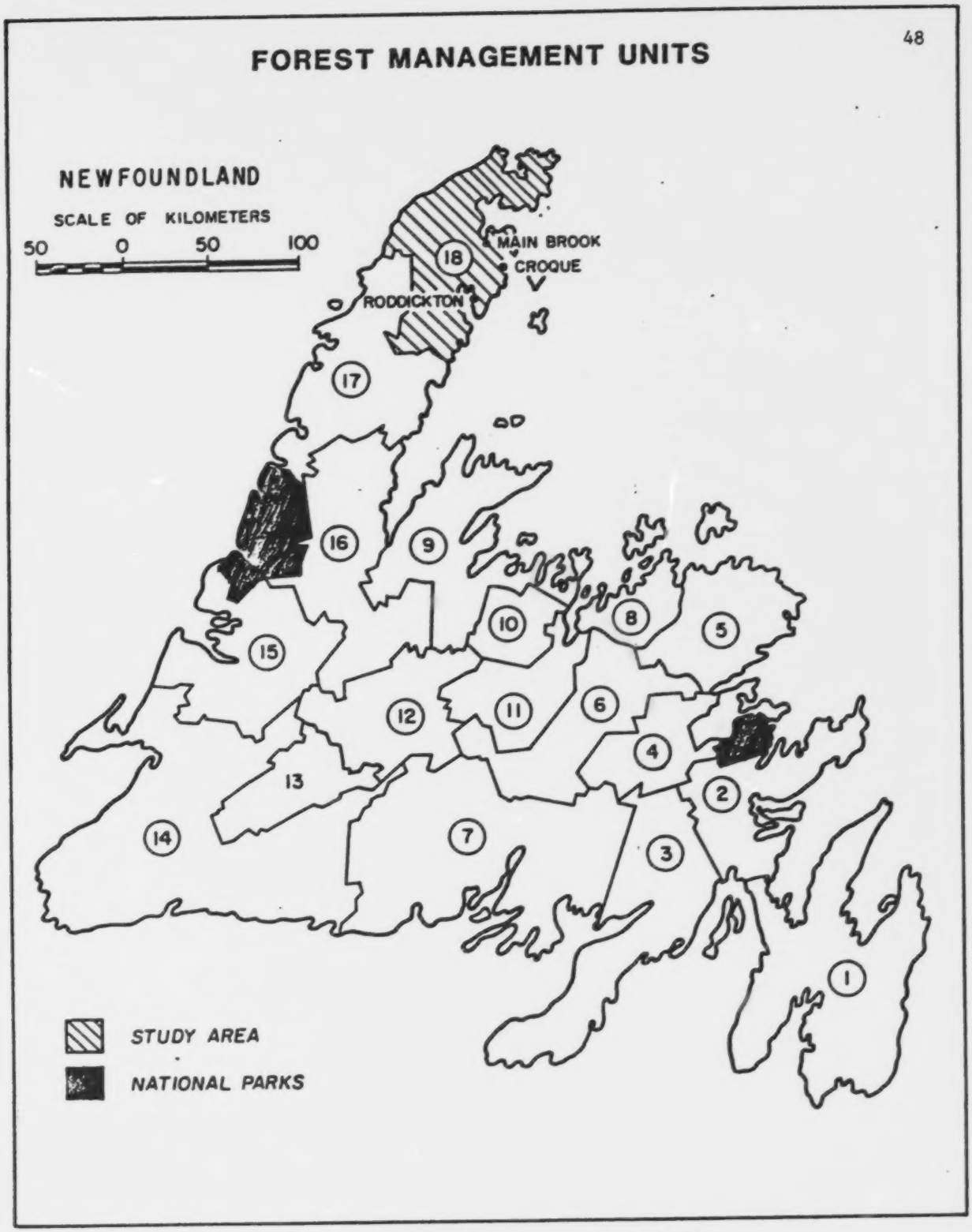



Figure 8.1 - Department of Forest Resources and Lands
Forest Management Unit

TABLE 8.1. Productive forest area by age class for Management Unit 18

| Age class | Productive forest area in ha | % of productive forest area in each age class |
|---|---|---|
| Disturbed | 8,315 | 6 |
| 0-20 | 12,266 | 9 |
| 21-40 | 23,842 | 18 |
| 41-60 | 8,004 | 6 |
| 61-80 | 8,749 | 7 |
| 81+ | 70,744 | 54 |
| | 131,920 | 100 |

TABLE 8.2. Gross merchantable volume by working group and age class for Management Unit 18

| Working Group | Mature vol. $m^3$ | Overmature vol. $m^3$ | % Overmature |
|---|---|---|---|
| Balsam fir | 1,743,772 | 8,050,325 | 82 |
| Black spruce | 15,241 | 724,399 | 98 |
| Hardwood softwood | 2,630 | - | 0 |
| Softwood hardwood | 32,770 | 55,779 | 63 |
| White birch | - | - | - |
| | 1,794,413 | 8,830,503 | 83 |

Note: Tables 8.1 and 8.2 were derived from information obtained from the Inventory Division, Department of Forest Resources and Lands.

## 8.1 - Present Demand on Resource

The Roddickton/Main Brook region has had a long history of logging for both pulpwood and sawlogs. Overall production in the area has declined significantly in recent years. There was a significant drop in lumber production after the closure of the Canada Bay Lumber Mill. Pulpwood markets now are almost non-existent due to the high cost of transportation to the mills in central and western Newfoundland.

The annual allowable cut for what is referred to as supply zone 3, or that area in the vicinity of Roddickton and Main Brook, is 120,000 $m^3$. Present demand for wood by all users in that area is approximately 30,000 - 40,000 $m^3$. Although these estimates are presently under review by the unit staff, they do show that there is a significant excess of wood in the area.

## 8.2 - Biomass Available for Wood-Fueled Plants

The Forest Management Supervisor in Roddickton was contacted to ascertain the amount of biomass that could be made available for wood-fueled plants. Tables 8.3 and 8.4 summarize Mr. Colbert's response regarding the short-term availability of biomass in the Roddickton/Main Brook areas. Appendix A shows his specific response.

The type and quantity of biomass available in the area depends to a large extent on the presence or absence of an export pulpwood market. There are strong indications at present that large volumes of wood will be exported from the Roddickton/Main Brook area in the near future. If this occurs, there will be a market for pulpwood cut in the area and a possibility that the Canada Bay Lumber sawmill operation would again become viable. Since the pulpwood export market is not certain, Mr. Colbert developed two possible scenarios or options for the short-term availability of biomass in the unit.

### Option 1

Three assumptions were made regarding the availability of biomass under option 1. The first assumption was that an export woods operation will be started in the unit. A second assumption was that an export market will exist for pulpwood cut during sawlog operations. The third assumption was that specified sawmills will operate at anticipated production levels.

TABLE 8.3. Annual biomass volumes available for a five-year period under option #1.

| Mill no. and export operation | Annual Production | | Biomass Potential $m^3$ | | | | |
|---|---|---|---|---|---|---|---|
| | Lumber (M.M.) | Pulpwood ($m^3$) (for export market) | Rot[1] | Birch[2] | Slabs and sawdust[3] | Bark[4] | Total |
| Export operation | Nil | 19,229 | 962 | 641 | nil | 1,923 | 3,526 |
| 1 | 3.0 | 19,229 | 3,846 | 1,123 | 5,784 | 1,923 | 12,676 |
| 2 | 1.0 | 9,615 | 962 | 481 | 1,928 | 962 | 4,333 |
| 3 | 0.5 | 2,404 | 962 | 160 | 964 | 240 | 2,326 |
| 4 | 0.3 | 1,442 | 288 | 96 | 578 | 144 | 1,106 |
| 5 | 1.0 | 4,807 | 962 | 321 | 1,928 | 481 | 3,692 |
| 6 | 0.3 | 2,404 | 385 | 128 | 578 | 240 | 1,331 |
| TOTAL | 6.1 | 59,130 | 8,367 | 2,950 | 11,760 | 5,913 | 28,990 |

1. Rot determined from Unit experience and forest inventory information with varying amounts for different situations.
2. Birch determined as 1 $m^3$ per 30 $m^3$ pulpwood and sawlogs.
3. Slabs and sawdust combined 40%. Information from Paul Duffett.
4. Bark - % used is 10%. Realistically 15% is more common.

TABLE 8.4. Annual biomass volumes available for a five-year period under option 2

| Mill no. and salvage area | Annual Production (M.M.) | Biomass potential $m^3$ Pulpwood[1] | Slabs and sawdust[2] | Birch[3] | Total |
|---|---|---|---|---|---|
| Salvage areas | - | 19,229 | - | 641 | 19,870 |
| 1 | - | - | - | - | - |
| 2 | 1.0 | 9,615 | 1,928 | 481 | 12,024 |
| 3 | 0.5 | 2,405 | 964 | 160 | 3,529 |
| 4 | 0.3 | 1,442 | 578 | 96 | 2,116 |
| 5 | 1.0 | 4,807 | 1,928 | 320 | 7,055 |
| 6 | 0.3 | 480 | 578 | 64 | 1,122 |
| TOTAL | 3.1 | 37,978 | 5,976 | 1,762 | 45,716 |

1. Pulpwood available for wood energy in the event no export market is available.

2. 40% of total volume round logs.

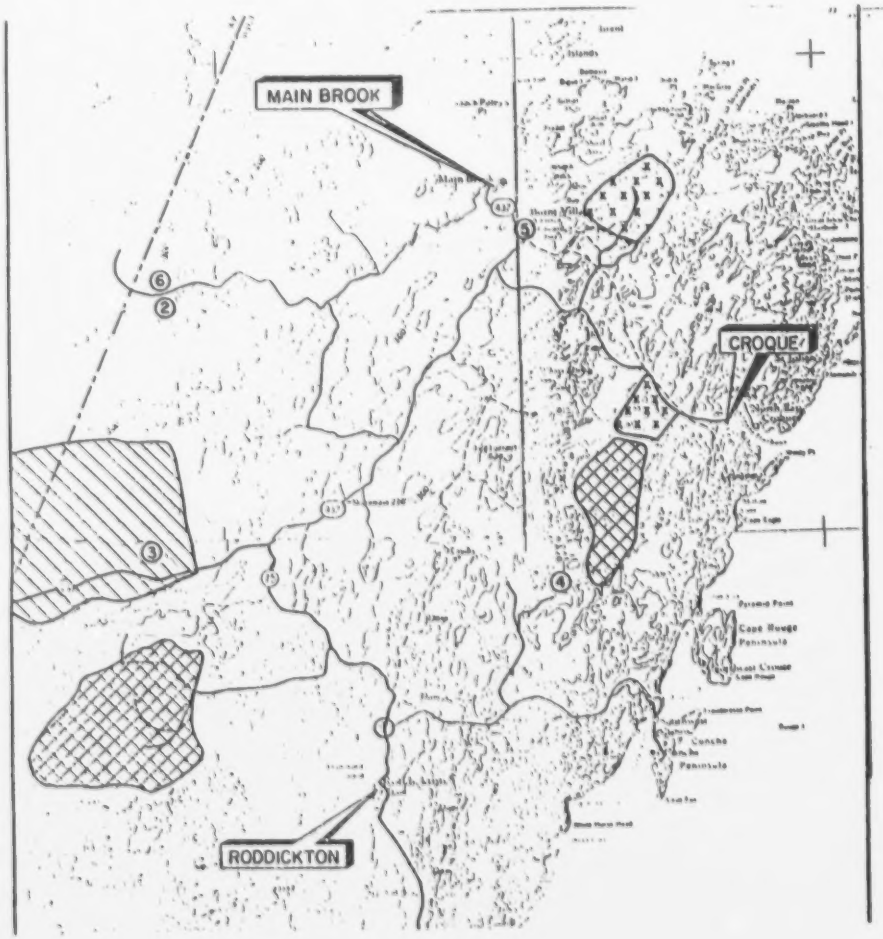
3. 1 $m^3$ birch per 30 $m^3$ pulpwood and sawlogs.

Table 8.3 shows the annual biomass volumes available for a five year period under option #1. The export operation referred to in the table would be set up in two areas containing large volumes of dead and dying trees (Figure 8.2). This operation would produce 19,229 $m^3$ of pulpwood annually for export in the next five years. As a result of the export operation, 3,526 $m^3$ of biomass would be available for wood fuel. The six sawmills referred to in the table wood produce 6.1 M.M. board feet of lumber and 39,901 $m^3$ of pulpwood for export. This would result in the availability of another 25,464 $m^3$ of biomass for fuel. The total amount of biomass available under option 1 would be 28,990 $m^3$.

**Option 2**

Under the second option, two assumptions were made. The first was that no export market will be found. The second assumption was that the sawmills in the area will operate at anticipated production levels with Canada Bay Lumber remaining closed.

Table 8.4 shows the annual biomass volumes available for a five year period under option 2. The export operation referred to in option 1 is non-existent in this option. Instead, 19,229 $m^3$ of pulpwood would be available for fuel. Five of the six mills referred to in option 1 would remain open with individual production levels being the same as in option 1. The 18,749 $m^3$ of pulpwood generated from the sawlog operations for the five mills would be available for fuel instead of the export market. A total of 3.1 M.M. board feet of lumber would be produced annually from the mills while another 5,976 $m^3$ of mill waste would be generated from the mill operations. In summary, under the second option, 45,716 $m^3$ of biomass would be made available for fuel.




DISTANCE CHART IN KILOMETRES

| Mill | Roddickton | Main Brook | Croque |
|---|---|---|---|
| 1 | 4 | 45 | 58 |
| 2 | 56 | 26 | 49 |
| 3 | 29 | 37 | 49 |
| 4 | 22 | 63 | 75 |
| 5 | 45 | 4 | 21 |
| 6 | 56 | 27 | 49 |

Figure 8.2 Study area showing sources of biomass

## 8.3 - Biomass Weight Summary

The biomass summaries obtained from the Forest Management supervisor were shown in solid $m^3$. These were later converted by the author to green tonnes. The conversion factors used were from Jessome (1977).

A moisture content of 45% on a wet basis was assumed for the biomass. The conversion factor for balsam fir (.6 tonnes per $m^3$) was assumed for the pulpwood, slabs and sawdust, rotten wood and bark. A conversion factor of .9 tonnes per $m^3$ was used for birch.

Tables 8.5 and 8.6 show the biomass potential for options 1 and 2 respectively in green tonnes.

TABLE 8.5. Weight of biomass in green tonnes[1] available annually for five years under option 1.

| Mill no. and export operation | Rot | Birch | Slabs and sawdust | Bark | Total |
|---|---|---|---|---|---|
| Export operation | 577 | 577 | - | 1,154 | 2,308 |
| 1 | 2,308 | 1,011 | 3,470 | 1,154 | 7,943 |
| 2 | 577 | 433 | 1,157 | 557 | 2,744 |
| 3 | 577 | 144 | 578 | 144 | 1,443 |
| 4 | 173 | 86 | 347 | 86 | 692 |
| 5 | 577 | 289 | 1,157 | 289 | 2,312 |
| 6 | 231 | 115 | 347 | 144 | 837 |
| TOTALS | 5,020 | 2,655 | 7,056 | 3,548 | 18,279 |

1. Assuming a 45% moisture content on a wet basis.

TABLE 8.6. Weight of biomass in green tonnes available annually for five years under option 2.

| Mill no. and salvage areas | Pulpwood | Slabs and sawdust | Birch | Total |
|---|---|---|---|---|
| Salvage areas | 11,537 | - | 577 | 12,114 |
| 1 | - | - | - | - |
| 2 | 5,769 | 1,157 | 433 | 7,359 |
| 3 | 1,443 | 578 | 144 | 2,165 |
| 4 | 865 | 347 | 86 | 1,298 |
| 5 | 2,884 | 1,157 | 288 | 4,329 |
| 6 | 288 | 347 | 58 | 693 |
| TOTAL | 22,786 | 3,586 | 1,586 | 27,958 |

## 8.4 - Biomass Requirements for Wood-fueled Plants

Table 8.7 shows the estimated wood fuel requirements for the three potential plants over a five-year period. This table shows a total annual requirement ranging from 21,900 green tonnes in 1984 to 25,000 in 1988. On a per-site basis, Roddickton would require an average of about 19,000 green tonnes while Main Brook and Croque would require only 3,300 and 850 green tonnes respectively.

### 8.4.01 - Biomass Supply Versus Demand (Short-Term)

The short-term supply of biomass should be adequate to meet the Roddickton demand under both options, and for all three communities under option 2. Under option 2, the annual available biomass would be 27,958 green tonnes. These supply figures do not take into account biomass resulting from the operation of sawmills producing less than 100 M. board feet or the tops and branches of trees cut for pulpwood or salvage, or any of the 154,553 ha of scrub forest in the unit, therefore the supply estimates are conservative. If these additional factors are taken into account, the supply of biomass should be adequate to meet the demand for all three communities under option 1 as well (18,279 green tonnes available annually).

### 8.4.02 - Biomass Supply Versus Demand (Long-Term)

The long-term supply (20 years) of biomass should not pose any problems. The Forest Management supervisor could not comment as to the precise location or volumes available over the long-term. Precise locations of cutting operations would most likely be dictated by economics and stand vigor or health.

Unit 18 contains large volumes of overmature wood (8,830,503 $m^3$ or 5,298,302 green tonnes). This wood is vulnerable to insect attack and disease. As stands start to deteriorate, forestry officials will concentrate logging operations in those areas. Most likely over the next 20 years, supply will exceed demand. These stands will have to be harvested or they will be lost.

TABLE 8.7. Estimated wood fuel requirements by generating stations in green tonnes.

| Year | Roddickton | Main Brook | Croque | Total |
|---|---|---|---|---|
| 1984 | 18,000 | 3,100 | 800 | 21,900 |
| 1985 | 18,500 | 3,200 | 825 | 22,525 |
| 1986 | 19,000 | 3,300 | 850 | 23,150 |
| 1987 | 20,000 | 3,400 | 875 | 24,275 |
| 1988 | 20,500 | 3,600 | 900 | 25,000 |

## 9.0 - SOCIO-ECONOMIC (OMNIFACTS RESEARCH LIMITED)

### 9.1 - Summary

**Present Population Growth and Unemployment Situation**

1. Although negative population growth has existed in the area during the years 1976 to 1981, the opening of a crab processing plant in 1983 will probably result in a positive population growth from 1981 to 1986.

2. There has been chronic unemployment since the closure of the Canada Bay Lumber Company Limited in 1980. What work is available is highly dependent on the fishery and is seasonal.

**Direct Consequences of Installation**

3. Electricity rates would likely remain the same.

4. Construction of a biomass fueled steam turbine generator would result in 80 to 100 months of work, with approximately $163,000 in wages accruing to community residents.

5. Power engineers as well as diesel operators will be required. There could be some re-alignments of duties of NLH personnel.

6. Environmental effects of noise pollution and condenser cooling water need to be evaluated. There should be positive effects on disposal of sawmill residue and present boiler stack emissions.

**Indirect Consequences of Installation**

7. Installation of the generator would contribute to the overall feasibility of the forest industries in the Roddickton area through the purchase of wood chips from local sources.

8. As outlined in Northlands Associates reports, sufficient wood is available in Forest Management Unit Number 18.

9. The lumber market is somewhat unstable in the Province because of the dependence on the residential construction industry in Mainland Canada and the United States. Strong markets appear to exist for pulpwood during the next couple of years in Europe and Scandanavia.

10. Present sawmill facilities are in excellent condition, however, the addition of a stud mill would enhance the sawmill viability. A wood chipper operated either with the existing sawmill or independently would be necessary.

11. About 10,000 additional cords of softwood would need to be harvested to provide the 18,000 tonnes of wood chips need to fuel the proposed wood chip boiler. The present sawmill provides enough residue to make only 2,500 cords available.

12. The production of wood chips would provide direct employment for an estimated 23 people and indirectly would contribute to employing another 111 if the Canada Bay Lumber Company Limited begins full operation.

## 9.2 - Introduction

The following section provides an overview of the study area population, the labour force employment, the major economic activities and the future economic prospects in this area. The study area includes Roddickton, Bide Arm, Conche and Englee with emphasis on Roddickton because this community was defined as being the most feasible location for a biomass fueled steam turbine generator.

The impact on the study area of installing a biomass fueled steam turbine generator in Roddickton has also been examined in terms of the impact from the construction and operational phases. Specifically, the effect on electricity rates has been considered, as well as the employment and indirect benefits expected from construction of the generator, the operational requirements for the generator in comparison to the diesel and hydro plants, in terms of the manpower requirements and their qualifications, and the environmental consequences.

The indirect consequences of operating the biomass fueled steam turbine generator have also been examined in terms of the provision of fuel for the generator. The future prospects for logging and sawmilling and the impact of wood chip production are discussed.

## 9.3 - Community Profile

### 9.3.1 - Demographic Characteristics

Population, age distribution and population growth trends are detailed in Table 9.1.

Table 9.1: Population Statistics for Roddickton Area

| Community | 1981 Population Male | Female | Total | Change Since 1976 | Annual Growth Rate Since 1976 | Percent of Population Under Age 35 |
|---|---|---|---|---|---|---|
| Bide Arm | 169 | 170 | 339 | +34 | +2.2% | 75 |
| Conche | 254 | 210 | 464 | +33 | +1.5% | 60 |
| Englee | 518 | 480 | 998 | + 9 | +0.2% | 65 |
| Roddickton | 602 | 540 | 1142 | -92 | -1.5% | 70 |
| Total | 1543 | 1400 | 2943 | -16 | -0.1% | 67 |

Source: 1981 Census

The negative growth rate, particularly prominent in the Roddickton area, is probably a result of the declining activity at Canada Bay Lumber Company Limited in the late 1970's. This company was the major employer in Roddickton until the plant closed in 1981 due to soft pulpwood and lumber markets.

However, the opening of a crab processing plant in 1983, employing approximately 250 persons, has probably contributed to a reversal of this trend and it is likely that the 1986 census will show a positive growth rate.

### 9.3.2 - Labour Force and Employment

Labour force characteristics for the study area are difficult to obtain on an accurate basis. Neither Canada Employment and Immigration Commission (CEIC) or Statistics Canada keep detailed employment statistics for specific communities. Statistics of employment and unemployment are obtained through statistical sampling and therefore can only be used to provide information

on a macro scale. A profile of unemployment insurance claimants for July, 1984 has been requested from CEIC but had not been received at the time of writing.

The White Bay Central Development Association did, however, conduct a survey of employers in May, 1984 regarding employment in the summer of 1983. The profile shown in Table 9.2 is constructed from figures provided by telephone from Ms. Barbara Boyd, Development Association Coordinator and from Mr. Norman Roebothan, Manager of the CEIC District Office in St. Anthony, and is estimated to be reasonably representative of the existing employment situation. Since little is known about the original method of collection of these data and the corresponding numbers of U.I.C. recipients at the time of the survey, it is difficult to identify labour force figures and unemployment rates.

Of the total employment of 1,277 in the Summer of 1983, however, 670 jobs were in fish processing and 259 in fishing. Hence, 929 employed people or 73% of the total number employed were fishery dependent. These are strictly seasonal jobs with plants in the area operating between May and October. For the remainder of the year, therefore, unemployment is very substantial.

Table 9.2. Estimate of Peak Employment by Community for Summer, 1984.

| | Persons Employed by Community (Annual Peak) | | | |
|---|---|---|---|---|
| | Roddickton | Bide Arm | Englee | Conche |
| Number of Business | 28 | 5 | 15 | 15 |
| Full-Time Employment | 136 | 11 | 52 | 25 |
| Part-Time Employment | 294 | 76 | 15 | 60 |
| Seasonal Employment | 309 | 111 | 425 | 150 |
| **By Sector:** | | | | |
| Government and Utilities | 34 | 2 | 10 | 5 |
| Health, Education and Churches | 45 | 5 | 25 | 7 |
| Sawmilling and Logging (private sector) | 31 | 20 | - | - |
| Fish Processing | 250 | 110 | 250 | 60 |
| Fishery | 20 | 30 | 93 | 116 |
| General Trade | 37 | 8 | 25 | 15 |
| Totals | 417 | 175 | 403 | 203 |

TOTAL FOR ALL COMMUNITIES

## 9.4 - Community Overview

According to the 1981 census, the total population of the four communities in the study area, (Roddickton, Bide Arm, Englee and Conche), is 2,943 with an overall negative annual growth of 0.1% since 1976. This negative growth rate may since have reversed to a positive rate due to the opening of a crab plant in Roddickton in 1983 employing some 250 workers on a seasonal basis.

(i) Roddickton

The largest community is Roddickton with a population of 1,142. The community serves as the focal point of the Canada Bay area being the centre of commercial and government activity. Historically, Roddickton was built on forest industries, both lumber and pulpwood production, and woods operations have been undertaken there since 1906. Traditionally, small sawmills operated in the area until the establishment of a new sawmill/planning mill complex in 1973 by Canada Bay Lumber Company Limited, a subsidiary of Chester Dawe Limited of St. John's.

Employment in the private sector of logging and sawmilling has ranged from 110 in 1943 to 56 in 1979. In 1943, 100 persons were employed by small independent sawmillers and logging enterprises with only 10 employed by a major sawmill. By 1979, only six persons were independently employed, with Canada Bay Lumber employing 20 in their own woods operations and 30 in the sawmill/-planing complex. Thus the result of the large complex has been the virtual elimination of independent operators, both in the woods and in sawmilling[1].

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[1]Hoddinott, S.W., Chairman, "Report on Roddickton/Main Brook Task Force on Economic Potential and Development", Government of Newfoundland, St. John's, February, 1980, p. 37.

The capacity of the sawmill/planing complex is five million FBM annually with actual production figures shown in Table 9.3.

Table 9.3. Lumber and Pulp Wood Production by Canada Bay Lumber Company Limited.

| Year | Lumber Production MMFBM Annually | Pulp Wood Production Cords Annually |
|---|---|---|
| 1974 | 3.4 | 7,800 |
| 1975 | 1.5 | nil |
| 1976 | 4.5 | 3,350 |
| 1977 | 4.5 | nil |
| 1978 | 1.5 | 1,225 |
| 1979 | 1.3 | 3,000 |
| TOTAL | 16.7 | 15,375 |

Source: Report on Roddickton/Main Brook Task Force[1]

The fluctuations evident in Table 9.3 reflect the consequences of many variables, the most significant of which were the changing role of independent sawmillers, labour disputes and the impact of lumber and pulpwood markets.

With a four million FBM breakeven point for sawmilling, the 1979 production of 1.3 million FBM was hardly adequate to sustain the operation. The final elimination of the pulpwood market in 1980 resulted in the closure of the plant and it has not been operational since then.

[1]Ibid, p.44

The resultant unemployment in Roddickton since the Canada Bay Lumber closure has been chronic. However, the opening of a crab plant by Canada Bay Seafood Company Limited, early in 1984, has done much to alleviate this situation even though the vast majority of the 250 seasonal employees are female and the wages are lower than those for men in logging and sawmilling.

**(ii) Bide Arm**

Bide Arm is a small community of 339 persons located about equi-distant between Roddickton and Englee. The focal point of this community is the small groundfish filleting plant operated by Fishery Products International Limited as a feeder for the parent plant at Englee. This plant is the principal employer in the community with a seasonal peak employment of approximately 110 plant workers. There are 30 full and part-time fisherman operating from Bide Arm with some 20 persons engaged in sawmilling and logging (probably related to both government and private sector activities in the Roddickton area).

**(iii) Englee**

The economy of Englee has always been based on the fishing industry with a fully integrated plant operated by Fishery Products International employing approximately 250 plant workers from May through November. The community has a population of 990 persons and about 90 full-time and part-time fishermen.

With the severe difficulties experienced by the fishing industry over the past several years, Englee has experienced considerable fluctuation in the fortunes of its plant workers and fishermen. Thus far, 1984 has been a poor year with ground fish generally scarce. With the season now well past its peak and nearing its conclusion, it will not have been a prosperous year in Englee.

**(iv) Conche**

The United Maritime Fishermen operate a fish processing plant in Conche employing some 65 to 79 people at the seasonal peak. The plant has a freezing unit but no cold storage and is therefore unable to hold finished goods inventory.

Installation of cold storage is dependent upon the provision of three phase power, not available in Conche at this time. Estimates, obtained in 1979, to install three phase power were $210,000 with $3,800 annual maintenance costs.[1] It is unlikely that such installation would be undertaken for one customer without a considerable capital contribution well beyond the customer's capability.

Conche has a population of 464 persons with approximately 116 full-time and part-time fishermen. Many of these fishermen sell their fish to the plant at Englee.

## 9.5 - Direct Consequences of Installation

### 9.5.1 - Construction

Information provided elsewhere in this study indicates that construction would result in 80 to 100 months of work.

It is anticipated that the contractor would use local labour whenever possible. The only imported workers would be for skills not available in the area.

Using local labour rates and approximately 80 work-months for construction, construction wages accruing to community residents are estimated at $130,000. It is not anticipated that difficulty

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[1]Ibid, p. 58

would be experienced in obtaining the necessary skills within the study area, no problems are anticipated with the labour force.

As far as the purchase of local materials is concerned, it is expected that this would be minimal. Boiler and turbine components and electrical switching and protective equipment would be imported from the mainland. Local dealers would be unlikely to stock even modest amounts of miscellaneous requirements for wiring and piping, etc. Local purchases, therefore, would be restricted to "pick-up" items such as cleaning materials, miscellaneous lumber, screws, nails, and other minor hardware items.

### 9.5.2 - Operations Employment

Newfoundland and Labrador Hydro, at present, employs nine people in Roddickton on a full-time basis.

Four full-time workers are employed in plant and line maintenance together with two seasonal and part-time employees.

It is anticipated that the installation of a steam generating unit will involve some re-assignment of duties and possibly an increase in operating personnel. The personnel requirements will require study by Newfoundland and Labrador Hydro before implementation.

After a general discussion with Hydro personnel, it was felt that the maximum total increase in resulting operating costs would be $60,000/yr. (Additional maintenance costs are treated separately.)

## 9.5.3 - Environmental Consequences

The environmental consequences of the thermal installation are related to:

(i) harvesting for wood chip fuel;
(ii) boiler stack emissions;
(iii) noise pollution; and
(iv) condenser cooling water.

Insofar as harvesting consequences are concerned, the effect will be favourable to the community in that the thermal unit will provide a means of disposal for the residue of sawmill production, insect infected trees, and over mature timber stands, which would otherwise be left in the environment to rot. If tree tops, the by-product of sawlog harvesting, are used as chips, silviculture efforts will be enhanced through the removal of this material from cut-over areas.

As previously noted the stack emissions from wood burning units are environmentally acceptable. Since the diesel units will be used for peaking and stand-by, the overall net effect will likely be that less pollutants will escape to the atmosphere.

cording to Mr. Chris Decker, Mayor of Roddickton, noise from existing diesel units is the source of frequent complaints h residents living in close proximity to the diesel plant. e the diesels will operate at peak periods only after the illation of the thermal unit, an evaluation of the effect oise from the steam turbine will have to be conducted.

### 9 Indirect Consequences

Th t likely positive impact of establishing a wood chip fu team turbine generator is that the purchase of wood

chips from local sources would contribute to the overall feasibility of the forest industries in the Roddickton Area. In particular, the re-activation of the sawmill/planer facilities owned by Chester Dawe Limited has, during the first half of 1984, been under active consideration by potential purchasers of the facility and it is quite possible that a decision to proceed could ultimately depend upon the final decision to proceed with the thermal installation.

This statement must be viewed with caution; several other factors are also of prime importance such as lumber market outlook, prospects for export pulpwood, the type of labour-management climate which can be developed, the availability of purchase financing, interest rates, etc. An evaluation of the Chester Dawe facility undertaken by W.W. Calvert and Associates of Nova Scotia in November, 1983 for Messrs. Chris and Clavin Decker of Roddickton, potential purchasers of the mill, suggests that reasonable potential exists for the enterprise to achieve a breakeven position in its second year of operation, exclusive of the utilization of wood chips for electricity generation[1]. Even with the sale of wood chips for an electricity generator, the potential success of the operation if it were re-opened by its present owner remains a question due to a severe labour relation problem experienced during previous years and the resultant negative attitude towards the company alleged to exist in the community.

The Calvert Report suggests that, with 5 MMFBM annual production, the plant could provide 2,500 cords of wood chips from sawmill residue providing a strong possibility for breakeven in the first year of operation.

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[1]W.W. Calvert and Associates, "Evaluation of the Proposed Purchase of the Assets Canada Bay Lumber Limited and The Restablishment of the Lumber Manufacturing Facility", prepared for Messrs. Chris and Melvin Decker, Roddickton, November, 1983.

## 9.6.1 - Future Prospects for Logging and Sawmilling

### 9.6.1.1 - The Resource

The area in which wood is, and would be harvested, for a sawmilling/ pulpwood operation at Roddickton is known as Forest Management Unit Number 18 which may be generally described as all that portion of the Northern Peninsula north of a line drawn approximately between Williamsport in White Bay to St. Genevieve Bay at the south-west entrance to the Strait of Belle Isle.

All sources consulted indicate more than sufficient forest resource to supply a sawmilling operation with a 5MMFBM annual productive capacity. Furthermore, according to the Calvert report, the Provincial Government has indicated its committment to allocate sufficient timber resources for the proposed re-opening of the sawmill.

Calvert, in co-operation with officials of the Provincial Department of Forest Resources and Lands, undertook an evaluation of the resource and identified an annual allowable cut for Unit Number 18 of 61,000 cords which converts to approximately 30.6 MMFBM or, assuming a one-to-one relationship, on average, between saw logs and pulpwood, a little over 15 MMFBM net annual allowable cut available for saw logs.

On the assumption that the Canada Bay Lumber Limited production would be 5 MMFBM annually, 10 MMFBM would be available for other operations.

Viewed in another context, the total sawlog volume of Unit Number 18 is estimated at 126 MMFBM, and a 10 year plant write-off life, 50 MMFBM will be required leaving 76 MMFBM for other operations.

According to the Roddickton/Main Brook Task Force report, even when the Canada Bay Lumber Company Limited experienced peak production between 1974 and 1977, only 45% of the annual allowable cut was being utilized.

Other factors, however, govern the accessibility and suitability of the resource and its mere existence does not assure its effective utilization. Many areas are comprised of overmature stands while others have been heavily infested with spruce budworm. Forestry officials are anxious that such stands be harvested as quickly as possible.

In Calvert's assessment, however, the resource is both accessible and suitable provided that government and private operators co-operate to ensure that harvesting results in complete and efficient removal of merchantable timber so as to optimize the utilization of the resource.

**9.6.1.2 - The Markets**

The Canada Bay Lumber Company Limited operation in Roddickton is primarily a lumber operation with pulpwood being a harvesting by-product as, of course, the wood chips would be for a wood boiler installation. The market for lumber, therefore, is of prime importance.

The breakeven analysis undertaken by Calvert on the Canada Bay Sawmill was based upon an average market price for lumber at Atlantic Province's sawmills of approximately $300.00 per MMFBM (F.O.B. Plant) in the fall of 1983.

In conversation with Randolph Clements, plant manager of the Roddickton facility, it was learned that potential purchasers in Newfoundland are now prepared to pay $325.00 per MFBM (September, 1984) and that based upon an apparent strong solidification

of the marketplace, preparations are underway for this sawmill to open for production in the final week of September. Negotiations are proceeding for the sale of pulpwood which is being stockpiled on reasonable expectations of sales contracts materializing.

The lumber market in Newfoundland is far more dependent on Mainland Canada and the United States residential construction than on its own residential construction industry. A slack market outside of Newfoundland results in the distress selling of Mainland lumber in the Province at a price which bears little relationship to costs. Newfoundland, of course, has nowhere to "dump" its production and therefore, when such market conditions exist, operators must cease further production. This is the traditional pattern of the sawmilling industry in Newfoundland.

Concerning the domestic pulpwood market, the difficulties experienced by the pulp and paper industry over the past several years have resulted in negligible sales from Canada Bay Lumber Company Limited to Newfoundland mills. In Calvert's analysis, a quotation of $77.50 per cord of pulpwood, C.I.F. Corner Brook, was received from Bowaters in Corner Brook but with an indication that their 1984 supply has already been established through traditional contractors and their own woods operations. At a delivered cost of $93.00 per cord with delivery costing about $47.00 per cord, Canada Bay Lumber Company Limited would lose $15.00 per cord if, in fact, the market existed. Hence, the sale of domestic pulpwood by the sawmill could only be feasible if it were a by-product of lumber production and sales were viewed as a contribution to overhead only.

Export markets for pulpwood appear to offer better prospects for Canada Bay Lumber Company Limited than domestic markets. Considerable volumes of export pulpwood have been shipped from Roddickton in the past and prices of $100.00 per cord, delivered dockside, have been obtained. At a cost of about $50.00 per

cord, delivered dockside the Roddickton, such markets could be very attractive. While the loss of such markets was one of the principal reasons for the closure of the Canada Bay Sawmill, these markets are anticipated to return strongly over the next several years, particularly Europe and Scandanavia.

Nevertheless, the Calvert Report does not include a pulpwood market in its breakeven analysis.

#### 9.6.1.3 - Existing Facilities

In their evaluation of the Canada Bay Sawmill, Calvert and Associates have assessed the plant equipment as being in excellent condition and well laid out. They have proposed the addition of a stud mill at a cost of about $50,000 thus enabling the company to use small diameter logs and tree tops, which would be otherwise sold as pulpwood or discarded, as sawlogs for lumber.

The plant would have to purchase a wood chipper if it were to supply wood chips to a wood burning boiler.

### 9.7 - Impact of Wood Chip Production

It has been previously identified in this report that about 17,000 to 23,000 tonnes of softwood chips per annum would be required to fuel the proposed wood chip boiler. If a cord of softwood is taken to weigh about 1.95 tonnes, the requirement would be for 9,000 to 12,000 cords. The Calvert Report estimates that the residue from the sawmill would result in the availability of about 2,500 cords for wood chip production, about one quarter of the total requirements. Therefore the following questions arise with respect to the provision of the remaining requirement:

(i) Can the additional harvesting required be accommodated within the annual allowable cut? The answer is clearly "yes" with an annual allowable cut of approximately 61,000 cords but the implication with respect to forest management would have to be seriously considered.

(ii) Would this requirement, in excess of the residue, be feasible for the Canada Bay Lumber Company Limited to produce? The optimum size of the chipper will have to be considered. The possibility exists for other operators to become involved in the supply of wood chips.

(iii) What would be the resultant employment from the supply of wood chips? If it is assumed that if Canada Bay Lumber Company Limited were to provide chips from their sawlogs residue, it is reasonable to assume that the chipping operation would be handled by existing employees, or with the addition of one employee at the most. If additional harvesting were undertaken, assuming a four man crew would harvest approximately 2,500 cords per year, 5.5 additional crews would be required or about 22 people in total.

Assuming that Canada Bay Lumber Company Limited did produce the initial 2,500 cords and that the balance was provided by the company or by other operators, it is reasonable to estimate that about 23 persons would be employed directly in the provision of wood chips.

In regard to the possible re-opening at the plant, the Calvert Report estimates a total of 45 persons would be required by the Company in logging, sawmilling and administration. About eleven of these persons would be in wood operations. Mr. Randolph Clements estimates a requirement of 75 persons in the woods operations including independent contractors.

An estimate of the total employment resulting from reactivation of the sawmill and the supply of wood chips is as follows:

| Employment Function | Number Employed |
|---|---|
| 1. Harvesting (under contract) | 64 |
| 2. Harvesting (Company employed) | 11 |
| 3. Sawmilling | 29 |
| 4. Administration | 5 |
| 5. Wood Chip Supply | 23 |
| Total direct employment | 132 |

If it is further assumed that the average employment would be for six months at an annual rate of $20,000 per annum, the additional wage benefit to the Roddickton area would be about $1,320,000 and employment at the seasonal peak in the area would be increased by about 32%.

## 10.0 - CONCLUSIONS AND RECOMMENDATIONS

### 10.1 - Conclusions

The principal conclusions of the study are as follows:

1. Electrical generation using woodchips and wood waste as fuel: It is technically feasible to install a steam turbine supplied by a wood·chip burning boiler in Roddickton for electrical generation. This system would replace some of the diesel fuel presently used. The base case payback period is just over 16 years.

2. Unit size: At this level of study, a unit of 1250 kW appears to be optimal. The capital cost of a larger unit is high, and it runs less efficiently at low loads. A smaller unit does not take full advantage of the fuel savings.

3. Other communities: The potential savings in fuel cost at Main Brook and Croque are too low to warrant the required capital expenditure, plus the additional costs of a power engineer.

4. Peat: There appears to be sufficient peat in the Roddickton area to supply the boiler, but a number of difficulties with peat harvesting and handling make production costs uncertain. If peat can be produced at the same cost as wood fuel then it could be used for power generation.

   A woodchip burning boiler which can accept peat as well as chips should be selected, so that if a peat harvesting pilot project is set up, the fuel could be used.

5. Gasification: Gasification is a promising technology, but at present is too expensive and too unreliable for a remote site.

6. Forest Resources: The quantity of chips required for the 1250 kW unit ranges from 19000 tonnes/year in the first year (1986) to over 23000 tonnes/year after 1993. A forest biomass inventory indicates that there is sufficient wood fuel available to meet these boiler requirements.

7. Socio-Economic Impact: The installation of a wood-chip burning boiler is expected to have a positive socio-economic impact on Roddickton. A considerable proportion of the fuel costs will remain in the community (paid to the wood chip suppliers), rather than being sent outside to the oil companies. Jobs will be created directly, in the supply of wood chips. Additional jobs will probably be created indirectly in the sawlog industry. At present, sawlog operations are not economical because there is no market for the lower quality wood (formerly sold as pulpwood). A market for the low quality material as woodchips would encourage the re-establishment of the sawlog industry.

8. Waste heat: Using the waste heat from the boilers directly in the operation (e.g. to dry chips) is questionable. Discussion with suppliers indicates that the reduction in stack temperature and associated problems exceed the benefits. The possibility of using the waste heat from the cooling towers to reduce the moisture content in the chips is possible and should be investigated at a later time if the project goes ahead. It is felt that to be truly viable, the project must be economical on power generation only. Some potential exists to use the waste heat in two nearby schools and a municipal building. Any use such as this would be a benefit to the project.

## 10.2 - Recommendations

The following recommendations are made as a result of this study.

1. Engineering work should be carried to sufficient detail to make a final selection of type and size of equipment. Technical discussions with Newfoundland and Labrador Hydro are required to consider how such a unit can be integrated into the system, both in terms of system stability and generation expansion planning. When the prices of equipment and fuel are firm, and the technical details have been worked out, a final decision can be made on project feasibility.

2. Investigations into the quality and quantity of peat in the area should continue, as well as into improved methods of production. If local peat were available, e.g. from a pilot project, it could be used to supply the wood chip boiler.

3. The possibility of using waste heat to heat nearby buildings and for fuel drying should be studied further, since this would provide additional benefits.

4. The possibility of a St. Anthony interconnection should be discussed further with NLH as this would change the Main Brook picture.

**REFERENCES**

Jessome, A.P. 1977. Strength and related properties of woods grown in Canada. Eastern Forest Products Lab., Ottawa, Canada. Forest Technical Rep. 21. pp. 37.

# Appendix A
# Detailed Calculations

Table A1
Woodchip Consumption

**Table A.1 (a): Woodchip Consumption 1983 Load Year**
**Total Load 7722 Mwh**

| Biomass Unit Size (kW) | Output Range (kW) | Avg. (kW) | Hours | Energy (MWh) | % Cap. | Steam Req'd (lbs/ hr) | Chip Consump. (tonnes/ hr) | Chips Req'd (tonnes year) |
|---|---|---|---|---|---|---|---|---|
| 2500 | 450- 600 | 500 | 6060 | 3030 | 20 | 12045 | 2.41 | 14600 |
| | 600-1250 | 900 | 1900 | 1710 | 36 | 18227 | 2.89 | 5500 |
| | 1250-1750 | 1500 | 850 | 1275 | 60 | 27690 | 3.87 | 3290 |
| | 1750-2500 | - | 0 | - | | | | |
| | 2500 | - | 0 | - | | | | |
| | | | | 6015 | | | | 23390 |
| | | | | | | | | (3.89) |
| 1750 | 450- 600 | 500 | 6060 | 3030 | 29 | 11333 | 1.89 | 11450 |
| | 600-1250 | 900 | 1900 | 1710 | 51 | 17434 | 2.53 | 4800 |
| | 1250-1750 | 1500 | 850 | 1275 | 86 | 27425 | 3.56 | 3030 |
| | 1750 | - | 0 | - | | | | |
| | | | | 6015 | | | | 19280 |
| | | | | | | | | (3.20) |
| 1250 | 450- 600 | 500 | 6060 | 3030 | 40 | 10439 | 1.59 | 9635 |
| | 600-1250 | 900 | 1900 | 1710 | 72 | 16990 | 2.29 | 4350 |
| | 1250 | 1250 | 850 | 1063 | 100 | 22906 | 2.87 | 2440 |
| | | | | 5803 | | | | 16425 |
| | | | | | | | | (2.83) |
| 600 | 450- 600 | 500 | 6060 | 3030 | 83 | 9609 | 1.26 | 7610 |
| | 600 | 600 | 2700 | 1620 | 100 | 11279 | 1.41 | 3810 |
| | | | | 4650 | | | | 11420 |
| | | | | | | | | (2.46) |

**Table A.1 (b): Annual Wood Chip Consumtion (1988 load year)**

| Biomass Unit Size (kW) | Output Range (kW) | Avg (kW) | Hours | Energy (MWh) | % Cap. | Steam Req'd (lbs/ hr) | Chip Consump. (tonnes/ hr) | Chips Req'd (tonnes/ year) | |
|---|---|---|---|---|---|---|---|---|---|
| 2500 | 600-1250 | 815 | 7000 | 5705 | 33 | 17068 | 2.84 | 19915 | |
| | 1250-1750 | 1500 | 1000 | 1500 | 60 | 27690 | 3.87 | 3870 | |
| | 1750-2500 | 2125 | 650 | 1380 | 85 | 37565 | 4.88 | 3170 | |
| | 2500 | 2500 | 110 | 275 | 100 | 43344 | 5.43 | 600 | |
| | | | | 8860 | | | | 27555 | (3.11) |
| 1750 | 600-1250 | 815 | 7000 | 5705 | 47 | 16333 | 2.40 | 16815 | |
| | 1250-1750 | 1500 | 1000 | 1500 | 86 | 27002 | 3.51 | 3505 | |
| | 1750 | 1750 | 760 | 1330 | 100 | 31398 | 3.93 | 2990 | |
| | | | | 8535 | | | | 23310 | (2.73) |
| 1250 | 600-1250 | 815 | 7000 | 5705 | 65 | 15525 | 2.13 | 14910 | |
| | 1250 | 1250 | 1760 | 2200 | 100 | 22906 | 2.87 | 5050 | |
| | | | | 7905 | | | | 19960 | (2.53) |
| 600 | 600 | 600 | 8760 | 5260 | 100 | 11279 | 1.41 | 12380 | (2.35) |

Note: From Newfoundland Hardwoods data. 1 tonne/hr = 7826 lbs/hr steam at 75% capacity and 42% moisture content.

**Table A.1 (c): Woodchip Consumption 1995 load year**
**Load 13364 MWh**

| Biomass Unit Size (kW) | Output Range (kW) | Avg. (kW) | Hours | Energy (MWh) | % Cap. | Steam Req'd (lbs/ hr) | Chip Consump. (tonnes/ hr) | Chips Req'd (tonnes year) |
|---|---|---|---|---|---|---|---|---|
| 2500 | 800-1250 | 1000 | 2760 | 2760 | 40 | 19865 | 3.02 | 8345 |
| | 1250-1750 | 1350 | 5000 | 6750 | 54 | 25294 | 3.61 | 18070 |
| | 1750-2500 | 2000 | 900 | 1800 | 80 | 35488 | 4.67 | 4200 |
| | 2500 | 2500 | 100 | 250 | 100 | 43349 | 5.43 | 545 |
| | | | | 11560 | | | | 31160 |
| | | | | | | | | (2.70) |
| 1750 | 800-1250 | 1000 | 2760 | 2760 | 57 | 19289 | 2.72 | 7500 |
| | 1250-1750 | 1350 | 5000 | 6750 | 77 | 24847 | 3.31 | 16565 |
| | 1750 | 1750 | 1000 | 1750 | 100 | 31398 | 3.93 | 3935 |
| | | | | 11260 | | | | 28000 |
| | | | | | | | | (2.49) |
| 1250 | 800 | 800 | | | | | | |
| | 800-1250 | 1000 | 2260 | 2260 | 80 | 18850 | 2.48 | 5605 |
| | 1250 | 1250 | 6500 | 8125 | 100 | 22906 | 2.87 | 18655 |
| | | | | 10385 | | | | 24260 |
| | | | | | | | | (2.34 |
| 600 | N/A | 600 | 8760 | 5260 | 100 | 11279 | 1.41 | 12380 |
| | | | | | | | | (2.35) |

**Table A2**
**Optimization Runs, Base Case**

TABLE A.2 (a) BASE CASE
600 kW BIOMASS UNIT, CAPITAL COST $1.5875 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/L (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro .....1,300 MWh/yr

| YEAR | ANNUAL ENERGY | CHIP ENERGY (MWh) | DIESEL ENERGY (MWh) | DIESEL REQ'D (litres) | DIESEL COST/ LITRE | ANNUAL DIESEL COST | CHIPS UTILIZATION (t/MWh) | CHIPS REQ'D (tonnes) | WOOD CHIP COST/ TONNE | ANNUAL CHIPS COST | TOTAL COST CHIPS/ DIESEL SYSTEM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 8651 | 0 | 7351 | 2100286 | $0.336 | $705,696 | 2.42 | 0 | $0.00 | $0 | $705,696 |
| 1986 | 9132 | 4630 | 3202 | 914857 | $0.353 | $322,762 | 2.39 | 11066 | $31.00 | $343,037 | $665,798 |
| 1987 | 9634 | 4742 | 3592 | 1026286 | $0.370 | $380,177 | 2.37 | 11239 | $31.93 | $358,847 | $739,024 |
| 1988 | 10164 | 4855 | 4009 | 1145429 | $0.389 | $445,528 | 2.35 | 11409 | $32.89 | $375,226 | $820,754 |
| 1989 | 10452 | 4855 | 4297 | 1227714 | $0.408 | $501,411 | 2.35 | 11409 | $33.87 | $386,483 | $887,894 |
| 1990 | 10876 | 4855 | 4721 | 1348857 | $0.429 | $578,431 | 2.35 | 11409 | $34.89 | $398,078 | $976,509 |
| 1991 | 11295 | 4855 | 5140 | 1468571 | $0.450 | $661,257 | 2.35 | 11409 | $35.94 | $410,020 | $1,071,277 |
| 1992 | 11707 | 4855 | 5552 | 1586286 | $0.473 | $749,973 | 2.35 | 11409 | $37.02 | $422,320 | $1,172,294 |
| 1993 | 12114 | 4855 | 5959 | 1702571 | $0.496 | $845,199 | 2.35 | 11409 | $38.13 | $434,990 | $1,280,189 |
| 1994 | 12515 | 4855 | 6360 | 1817143 | $0.521 | $947,179 | 2.35 | 11409 | $39.27 | $448,040 | $1,395,219 |
| 1995 | 12933 | 4855 | 6778 | 1936571 | $0.547 | $1,059,902 | 2.35 | 11409 | $40.45 | $461,481 | $1,521,383 |
| 1996 | 13364 | 4855 | 7209 | 2059714 | $0.575 | $1,183,664 | 2.35 | 11409 | $41.66 | $475,325 | $1,658,990 |
| 1997 | 13801 | 4855 | 7646 | 2184571 | $0.603 | $1,318,187 | 2.35 | 11409 | $42.91 | $489,585 | $1,807,772 |
| 1998 | 14238 | 4855 | 8083 | 2309429 | $0.634 | $1,463,203 | 2.35 | 11409 | $44.20 | $504,273 | $1,967,476 |
| 1999 | 14675 | 4855 | 8520 | 2434286 | $0.665 | $1,619,426 | 2.35 | 11409 | $45.52 | $519,401 | $2,138,827 |
| 2000 | 15111 | 4855 | 8956 | 2558857 | $0.699 | $1,787,413 | 2.35 | 11409 | $46.89 | $534,983 | $2,322,395 |
| 2001 | 15548 | 4855 | 9393 | 2683714 | $0.733 | $1,968,359 | 2.35 | 11409 | $48.30 | $551,032 | $2,519,392 |
| 2002 | 15985 | 4855 | 9830 | 2808571 | $0.770 | $2,162,932 | 2.35 | 11409 | $49.75 | $567,563 | $2,730,495 |
| 2003 | 16422 | 4855 | 10267 | 2933429 | $0.809 | $2,372,041 | 2.35 | 11409 | $51.24 | $584,590 | $2,956,631 |

TABLE A.2 (a) BASE CASE PRESENT WORTH OF SAVINGS
600 kW BIOMASS UNIT, CAPITAL COST $1.5875 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/L (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,587,500 |
| 1986 | $789,466 | $60,000 | $8,000 | $55,667 | $49,263 | $1,538,237 |
| 1987 | $882,071 | $61,800 | $8,240 | $72,007 | $57,175 | $1,481,062 |
| 1988 | $985,074 | $63,654 | $8,487 | $92,178 | $63,884 | $1,417,178 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $105,735 | $64,849 | $1,352,329 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $120,237 | $65,260 | $1,287,069 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $135,741 | $65,199 | $1,221,870 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $152,305 | $64,739 | $1,157,131 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $169,991 | $63,944 | $1,093,187 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $188,863 | $62,870 | $1,030,317 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $208,990 | $61,566 | $968,751 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $230,443 | $60,076 | $908,675 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $253,300 | $58,438 | $850,238 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $277,639 | $56,684 | $793,554 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $303,545 | $54,844 | $738,710 |
| 2000 | $2,756,359 | $90,755 | $12,101 | $331,108 | $52,941 | $685,769 |
| 2001 | $2,985,753 | $93,478 | $12,464 | $360,420 | $50,998 | $634,771 |
| 2002 | $3,231,196 | $96,282 | $12,838 | $391,580 | $49,033 | $585,738 |
| 2003 | $3,493,718 | $99,171 | $13,223 | $424,693 | $47,061 | $538,677 |

TABLE A.2 (b) BASE CASE
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro .....1,300 MWh/yr

| YEAR | ANNUAL ENERGY | CHIP ENERGY (MWh) | DIESEL ENERGY (MWh) | DIESEL REQ'D (litres) | DIESEL COST/ LITRE | ANNUAL DIESEL COST | CHIPS UTILIZATION (t/MWh) | CHIPS REQ'D (tonnes) | WOOD CHIP COST/ TONNE | ANNUAL CHIPS COST | TOTAL COST CHIPS/ DIESEL SYSTEM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 8651 | 0 | 7351 | 2100286 | $0.336 | $705,696 | 2.71 | 0 | $0.00 | $0 | $705,696 |
| 1986 | 9132 | 6521 | 1311 | 374571 | $0.353 | $132,149 | 2.65 | 17281 | $31.00 | $535,700 | $667,849 |
| 1987 | 9634 | 6909 | 1425 | 407143 | $0.370 | $150,822 | 2.59 | 17894 | $31.93 | $571,365 | $722,187 |
| 1988 | 10164 | 7297 | 1567 | 447714 | $0.389 | $174,144 | 2.53 | 18461 | $32.89 | $607,157 | $781,301 |
| 1989 | 10452 | 7624 | 1528 | 436571 | $0.408 | $178,300 | 2.50 | 19060 | $33.87 | $645,649 | $823,949 |
| 1990 | 10876 | 7951 | 1625 | 464286 | $0.429 | $199,100 | 2.48 | 19718 | $34.89 | $687,993 | $887,093 |
| 1991 | 11295 | 8278 | 1717 | 490571 | $0.450 | $220,891 | 2.45 | 20281 | $35.94 | $728,852 | $949,743 |
| 1992 | 11707 | 8605 | 1802 | 514857 | $0.473 | $243,417 | 2.42 | 20824 | $37.02 | $770,817 | $1,014,234 |
| 1993 | 12114 | 8932 | 1882 | 537714 | $0.496 | $266,935 | 2.39 | 21347 | $38.13 | $813,896 | $1,080,831 |
| 1994 | 12515 | 9259 | 1956 | 558857 | $0.521 | $291,302 | 2.37 | 21944 | $39.27 | $861,731 | $1,153,034 |
| 1995 | 12933 | 9586 | 2047 | 584857 | $0.547 | $320,097 | 2.34 | 22431 | $40.45 | $907,298 | $1,227,395 |
| 1996 | 13364 | 9651 | 2413 | 689429 | $0.575 | $396,197 | 2.34 | 22583 | $41.66 | $940,854 | $1,337,050 |
| 1997 | 13801 | 9717 | 2784 | 795429 | $0.603 | $479,968 | 2.33 | 22641 | $42.91 | $971,537 | $1,451,505 |
| 1998 | 14238 | 9782 | 3156 | 901714 | $0.634 | $571,306 | 2.33 | 22792 | $44.20 | $1,007,377 | $1,578,683 |
| 1999 | 14675 | 9847 | 3528 | 1008000 | $0.665 | $670,579 | 2.32 | 22845 | $45.52 | $1,040,010 | $1,710,589 |
| 2000 | 15111 | 9912 | 3899 | 1114000 | $0.699 | $778,151 | 2.32 | 22996 | $46.89 | $1,078,281 | $1,856,433 |
| 2001 | 15548 | 9978 | 4270 | 1220000 | $0.733 | $894,804 | 2.32 | 23149 | $48.30 | $1,118,025 | $2,012,829 |
| 2002 | 15985 | 10043 | 4642 | 1326286 | $0.770 | $1,021,397 | 2.31 | 23199 | $49.75 | $1,154,072 | $2,175,468 |
| 2003 | 16422 | 10108 | 5014 | 1432571 | $0.809 | $1,158,412 | 2.31 | 23349 | $51.24 | $1,196,387 | $2,354,799 |

TABLE A.2 (b) BASE CASE, PRESENT WORTH OF SAVINGS
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $789,466 | $60,000 | $8,000 | $53,617 | $47,448 | $1,946,052 |
| 1987 | $882,071 | $61,800 | $8,240 | $89,843 | $70,360 | $1,875,691 |
| 1988 | $985,074 | $63,654 | $8,487 | $131,632 | $91,228 | $1,784,464 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $169,680 | $104,068 | $1,680,396 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $209,653 | $113,791 | $1,566,605 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $257,275 | $123,574 | $1,443,030 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $310,385 | $131,924 | $1,311,107 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $369,349 | $138,934 | $1,172,172 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $431,048 | $143,489 | $1,028,683 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $502,977 | $148,171 | $880,512 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $552,383 | $144,005 | $736,507 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $609,567 | $140,631 | $595,876 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $666,432 | $136,062 | $459,814 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $731,783 | $132,216 | $327,598 |
| 2000 | $2,756,359 | $90,755 | $12,101 | $797,071 | $127,444 | $200,154 |
| 2001 | $2,985,753 | $93,478 | $12,464 | $866,983 | $122,675 | $77,479 |
| 2002 | $3,231,196 | $96,282 | $12,838 | $946,607 | $118,532 | ($41,053) |
| 2003 | $3,493,718 | $99,171 | $13,223 | $1,026,526 | $113,752 | ($154,805) |

TABLE A.2 (c) BASE CASE
1750 kW BIOMASS UNIT, CAPITAL COST $2.6005 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/L (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro .....1,300 MWh/yr

| YEAR | ANNUAL ENERGY | CHIP ENERGY (MWh) | DIESEL ENERGY (MWh) | DIESEL REQ'D (litres) | DIESEL COST/ LITRE | ANNUAL DIESEL COST | CHIPS UTILIZATION (t/MWh) | CHIPS REQ'D (tonnes) | WOOD CHIP COST/ TONNE | ANNUAL CHIPS COST | TOTAL COST CHIPS/ DIESEL SYSTEM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 8651 | 0 | 7751 | 2100286 | $0.336 | $705,696 | 3.01 | 0 | $0.00 | $0 | $705,696 |
| 1986 | 9132 | 6948 | 884 | 252571 | $0.353 | $89,107 | 2.92 | 20288 | $31.00 | $628,933 | $718,040 |
| 1987 | 9634 | 7413 | 921 | 263143 | $0.370 | $97,479 | 2.82 | 20905 | $31.93 | $667,486 | $764,964 |
| 1988 | 10164 | 7878 | 986 | 281714 | $0.389 | $109,576 | 2.73 | 21507 | $32.89 | $707,318 | $816,894 |
| 1989 | 10452 | 8237 | 915 | 261429 | $0.408 | $106,770 | 2.70 | 22240 | $33.87 | $753,366 | $860,136 |
| 1990 | 10876 | 8597 | 979 | 279714 | $0.429 | $119,950 | 2.66 | 22868 | $34.89 | $797,883 | $917,833 |
| 1991 | 11295 | 8956 | 1039 | 296857 | $0.450 | $133,666 | 2.63 | 23554 | $35.94 | $846,482 | $980,148 |
| 1992 | 11707 | 9316 | 1091 | 311714 | $0.473 | $147,374 | 2.59 | 24128 | $37.02 | $893,129 | $1,040,503 |
| 1993 | 12114 | 9675 | 1139 | 325429 | $0.496 | $161,551 | 2.56 | 24768 | $38.13 | $944,307 | $1,105,858 |
| 1994 | 12515 | 10034 | 1181 | 337429 | $0.521 | $175,883 | 2.52 | 25286 | $39.27 | $992,965 | $1,168,849 |
| 1995 | 12933 | 10394 | 1239 | 354000 | $0.547 | $193,747 | 2.49 | 25881 | $40.45 | $1,046,836 | $1,240,584 |
| 1996 | 13364 | 10864 | 1200 | 342857 | $0.575 | $197,031 | 2.47 | 26834 | $41.66 | $1,117,946 | $1,314,977 |
| 1997 | 13801 | 11333 | 1168 | 333714 | $0.603 | $201,366 | 2.44 | 27653 | $42.91 | $1,186,604 | $1,387,970 |
| 1998 | 14238 | 11803 | 1135 | 324286 | $0.634 | $205,460 | 2.42 | 28563 | $44.20 | $1,262,456 | $1,467,916 |
| 1999 | 14675 | 12272 | 1103 | 315143 | $0.665 | $209,651 | 2.40 | 29453 | $45.52 | $1,340,825 | $1,550,476 |
| 2000 | 15111 | 12742 | 1069 | 305429 | $0.699 | $213,348 | 2.37 | 30199 | $46.89 | $1,416,018 | $1,629,366 |
| 2001 | 15548 | 13212 | 1036 | 296000 | $0.733 | $217,100 | 2.35 | 31048 | $48.30 | $1,499,535 | $1,716,635 |
| 2002 | 15985 | 13861 | 824 | 235429 | $0.770 | $181,308 | 2.32 | 32158 | $49.75 | $1,599,705 | $1,781,013 |
| 2003 | 16422 | 14151 | 971 | 277429 | $0.809 | $224,335 | 2.30 | 32547 | $51.24 | $1,667,668 | $1,892,003 |

TABLE A.2 (c) BASE CASE PRESENT WORTH OF SAVINGS
1750 kW BIOMASS UNIT, CAPITAL COST $2.6005 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/L (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $2,600,500 |
| 1986 | $789,466 | $60,000 | $8,000 | $3,425 | $3,031 | $2,597,469 |
| 1987 | $882,071 | $61,800 | $8,240 | $47,066 | $36,860 | $2,560,609 |
| 1988 | $985,074 | $63,654 | $8,487 | $96,039 | $66,560 | $2,494,049 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $133,492 | $81,873 | $2,412,176 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $178,913 | $97,107 | $2,315,069 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $226,870 | $108,970 | $2,206,100 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $284,096 | $120,758 | $2,085,342 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $344,322 | $129,520 | $1,955,821 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $415,233 | $138,225 | $1,817,597 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $489,789 | $144,286 | $1,673,311 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $574,456 | $149,759 | $1,523,551 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $673,102 | $155,289 | $1,368,263 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $777,199 | $158,676 | $1,209,586 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $891,896 | $161,145 | $1,048,441 |
| 2000 | $2,756,359 | $90,755 | $12,101 | $1,024,137 | $163,750 | $884,691 |
| 2001 | $2,985,753 | $93,478 | $12,464 | $1,163,177 | $164,585 | $720,106 |
| 2002 | $3,231,196 | $96,282 | $12,838 | $1,341,063 | $167,925 | $552,181 |
| 2003 | $3,493,718 | $99,171 | $13,223 | $1,489,321 | $165,035 | $387,146 |

TABLE A.2 (d) BASE CASE
2500 kW BIOMASS UNIT, CAPITAL COST $2.9666 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/L (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro .....1,300 MWh/yr

| YEAR | ANNUAL ENERGY | CHIP ENERGY (MWh) | DIESEL ENERGY (MWh) | DIESEL REQ'D (litres) | DIESEL COST/ LITRE | ANNUAL DIESEL COST | CHIPS UTILIZATION (t/MWh) | CHIPS REQ'D (tonnes) | WOOD CHIP COST/ TONNE | ANNUAL CHIPS COST | TOTAL COST CHIPS/ DIESEL SYSTEM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 8651 | 0 | 7351 | 2100286 | $0.336 | $705,696 | 3.58 | 0 | $0.00 | $0 | $705,696 |
| 1986 | 9132 | 6685 | 1147 | 327714 | $0.353 | $115,618 | 3.42 | 22863 | $31.00 | $708,744 | $824,361 |
| 1987 | 9634 | 7062 | 1272 | 363429 | $0.370 | $134,628 | 3.27 | 23093 | $31.93 | $737,351 | $871,980 |
| 1988 | 10164 | 7440 | 1424 | 406857 | $0.389 | $158,252 | 3.11 | 23138 | $32.89 | $760,973 | $919,225 |
| 1989 | 10452 | 7902 | 1250 | 357143 | $0.408 | $145,861 | 3.05 | 24101 | $33.87 | $816,414 | $962,274 |
| 1990 | 10876 | 8363 | 1213 | 346571 | $0.429 | $148,620 | 2.99 | 25005 | $34.89 | $872,457 | $1,021,077 |
| 1991 | 11295 | 8825 | 1170 | 334286 | $0.450 | $150,520 | 2.93 | 25857 | $35.94 | $929,245 | $1,079,764 |
| 1992 | 11707 | 9286 | 1121 | 320286 | $0.473 | $151,427 | 2.88 | 26744 | $37.02 | $989,934 | $1,141,360 |
| 1993 | 12114 | 9748 | 1066 | 304571 | $0.496 | $151,197 | 2.82 | 27489 | $38.13 | $1,048,062 | $1,199,259 |
| 1994 | 12515 | 10209 | 1006 | 287429 | $0.521 | $149,821 | 2.75 | 28075 | $39.27 | $1,102,492 | $1,252,313 |
| 1995 | 12933 | 10671 | 962 | 274857 | $0.547 | $150,432 | 2.70 | 28812 | $40.45 | $1,165,375 | $1,315,806 |
| 1996 | 13364 | 11500 | 564 | 161143 | $0.575 | $92,605 | 2.65 | 30475 | $41.66 | $1,269,631 | $1,362,236 |
| 1997 | 13801 | 12000 | 501 | 143143 | $0.603 | $86,374 | 2.60 | 31200 | $42.91 | $1,338,831 | $1,425,205 |
| 1998 | 14238 | 12500 | 438 | 125143 | $0.634 | $79,286 | 2.55 | 31875 | $44.20 | $1,408,830 | $1,488.118 |
| 1999 | 14675 | 13000 | 375 | 107143 | $0.665 | $71,278 | 2.50 | 32500 | $45.52 | $1,479,548 | $1,550,825 |
| 2000 | 15111 | 13500 | 311 | 88857 | $0.699 | $62,068 | 2.45 | 33075 | $46.89 | $1,550,896 | $1,612.965 |
| 2001 | 15548 | 14000 | 248 | 70857 | $0.733 | $51,970 | 2.40 | 33600 | $48.30 | $1,622,779 | $1,674.749 |
| 2002 | 15985 | 14500 | 185 | 52857 | $0.770 | $40,706 | 2.35 | 34075 | $49.75 | $1,695,092 | $1,735,798 |
| 2003 | 16422 | 15000 | 122 | 34857 | $0.809 | $28,186 | 2.30 | 34500 | $51.24 | $1,767,721 | $1,795,907 |

TABLE A.2 (d) BASE CASE PRESENT WORTH OF SAVINGS
2500 kW BIOMASS UNIT, CAPITAL COST $2.9666 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/L (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $2,966,600 |
| 1986 | $789,466 | $60,000 | $8,000 | ($102,896) | ($91,058) | $3,057,658 |
| 1987 | $882,071 | $61,800 | $8,240 | ($59,949) | ($46,949) | $3,104,607 |
| 1988 | $985,074 | $63,654 | $8,487 | ($6,293) | ($4,361) | $3,108,968 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $31,354 | $19,230 | $3,089,738 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $75,669 | $41,070 | $3,048,668 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $127,254 | $61,122 | $2,987,546 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $183,239 | $77,888 | $2,909,658 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $250,921 | $94,387 | $2,815,272 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $331,769 | $110,441 | $2,704,831 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $414,566 | $122,126 | $2,582,704 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $527,197 | $137,439 | $2,445,265 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $635,868 | $146,698 | $2,298,567 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $756,997 | $154,552 | $2,144,015 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $891,547 | $161,082 | $1,982,933 |
| 2000 | $2,756,359 | $90,755 | $12,101 | $1,040,539 | $166,373 | $1,816,561 |
| 2001 | $2,985,753 | $93,478 | $12,464 | $1,205,063 | $170,512 | $1,646,049 |
| 2002 | $3,231,196 | $96,282 | $12,838 | $1,386,278 | $173,587 | $1,472,462 |
| 2003 | $3,493,718 | $99,171 | $13,223 | $1,585,418 | $175,684 | $1,296,778 |

**Table A3**
**Sensitivities**

TABLE A.3 (a) BASE CASE, PRESENT WORTH OF SAVINGS
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $789,466 | $60,000 | $8,000 | $53,617 | $47,448 | $1,946,052 |
| 1987 | $882,071 | $61,800 | $8,240 | $89,843 | $70,360 | $1,875,691 |
| 1988 | $985,074 | $63,654 | $8,487 | $131,632 | $91,228 | $1,784,464 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $169,680 | $104,068 | $1,680,396 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $209,653 | $113,791 | $1,566,605 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $257,275 | $123,574 | $1,443,030 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $310,365 | $131,924 | $1,311,107 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $369,349 | $138,934 | $1,172,172 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $431,048 | $143,489 | $1,028,683 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $502,977 | $148,171 | $880,512 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $582,383 | $144,005 | $736,507 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $609,567 | $140,631 | $595,876 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $666,432 | $136,062 | $459,814 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $731,783 | $132,216 | $327,598 |
| 2000 | $2,756,359 | $90,755 | $12,101 | $797,071 | $127,444 | $200,154 |
| 2001 | $2,985,753 | $93,478 | $12,464 | $866,983 | $122,675 | $77,479 |
| 2002 | $3,231,196 | $96,282 | $12,838 | $946,607 | $118,532 | ($41,053) |
| 2003 | $3,493,718 | $99,171 | $13,223 | $1,026,526 | $113,752 | ($154,805) |

TABLE A.3 (b) BASE CASE, WITH LOW INTEREST RATE
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

| | | |
|---|---|---|
| Interest Rate | 10%/year | |
| Diesel Escalation Rate | 5%/year | |
| Wood Chip Escalation Rate | 3%/year | |
| Diesel Utilization Rate | 3.5 kWh/l | |
| Chip cost | $31.00/t | |
| Diesel cost | $0.320/l | (1984) |
| Additional Labour | $60,000/yr | |
| Labour Rate Escalation | 3%/year | |
| Additional Maintenance | $8,000/yr | |
| Maintenance Escalation | 3%/year | |
| Mini Hydro | 1,300 MWh/yr | |

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $789,466 | $60,000 | $8,000 | $53,617 | $48,742 | $1,944,758 |
| 1987 | $882,071 | $61,800 | $8,240 | $89,843 | $74,251 | $1,870,507 |
| 1988 | $985,074 | $63,654 | $8,487 | $131,632 | $98,897 | $1,771,610 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $169,680 | $115,894 | $1,655,716 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $209,653 | $130,178 | $1,525,538 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $257,275 | $145,225 | $1,380,313 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $310,365 | $159,266 | $1,221,047 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $369,349 | $172,304 | $1,048,743 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $431,048 | $182,806 | $865,936 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $502,977 | $193,920 | $672,017 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $552,383 | $193,607 | $478,410 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $609,567 | $194,227 | $284,183 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $666,432 | $193,042 | $91,141 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $731,783 | $192,701 | ($101,560) |
| 2000 | $2,756,359 | $90,755 | $12,101 | $797,071 | $190,812 | ($292,372) |
| 2001 | $2,985,753 | $93,478 | $12,464 | $866,983 | $188,681 | ($481,053) |
| 2002 | $3,231,196 | $96,282 | $12,838 | $946,607 | $187,281 | ($668,334) |
| 2003 | $3,493,718 | $99,171 | $13,223 | $1,026,526 | $184,630 | ($852,964) |

TABLE A.3 (c) BASE CASE, WITH LOW CHIP COST
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $29.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $789,466 | $60,000 | $8,000 | $88,178 | $78,034 | $1,915,466 |
| 1987 | $882,071 | $61,800 | $8,240 | $126,706 | $99,229 | $1,816,237 |
| 1988 | $985,074 | $63,654 | $8,487 | $170,803 | $118,275 | $1,697,962 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $211,335 | $129,615 | $1,568,347 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $254,040 | $137,883 | $1,430,464 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $304,298 | $146,160 | $1,284,304 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $360,095 | $153,062 | $1,131,242 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $421,859 | $158,686 | $972,556 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $486,644 | $161,996 | $810,559 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $561,513 | $165,515 | $645,044 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $613,083 | $159,809 | $485,235 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $672,247 | $155,091 | $330,144 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $731,424 | $149,331 | $180,793 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $798,380 | $144,339 | $36,454 |
| 2000 | $2,756,359 | $90,755 | $12,101 | $866,637 | $138,567 | ($102,113) |
| 2001 | $2,985,753 | $93,478 | $12,464 | $939,113 | $132,881 | ($234,994) |
| 2002 | $3,231,196 | $96,282 | $12,838 | $1,021,064 | $127,855 | ($362,850) |
| 2003 | $3,493,718 | $99,171 | $13,223 | $1,103,712 | $122,305 | ($485,155) |

TABLE A.3 (d) HIGH DIESEL RATE CASE
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

| | | |
|---|---|---|
| Interest Rate | 13%/year | |
| Diesel Escalation Rate | 7%/year | |
| Wood Chip Escalation Rate | 3%/year | |
| Diesel Utilization Rate | 3.5 kWh/l | |
| Chip cost | $31.00/t | |
| Diesel cost | $0.320/l | (1984) |
| Additional Labour | $60,000/yr | |
| Labour Rate Escalation | 3%/year | |
| Additional Maintenance | $8,000/yr | |
| Maintenance Escalation | 3%/year | |
| Mini Hydro | 1,300 MWh/yr | |

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $804,503 | $60,000 | $8,000 | $66,137 | $58,528 | $1,934,972 |
| 1987 | $915,993 | $61,800 | $8,240 | $117,966 | $92,384 | $1,842,587 |
| 1988 | $1,042,443 | $63,654 | $8,487 | $178,859 | $123,958 | $1,718,629 |
| 1989 | $1,151,655 | $65,564 | $8,742 | $239,423 | $146,842 | $1,571,787 |
| 1990 | $1,289,360 | $67,531 | $9,004 | $306,035 | $166,103 | $1,405,683 |
| 1991 | $1,439,981 | $69,556 | $9,274 | $384,930 | $184,889 | $1,220,794 |
| 1992 | $1,604,291 | $71,643 | $9,552 | $474,491 | $201,686 | $1,019,107 |
| 1993 | $1,783,725 | $73,792 | $9,839 | $575,769 | $216,581 | $802,525 |
| 1994 | $1,979,359 | $76,006 | $10,134 | $686,268 | $228,448 | $574,077 |
| 1995 | $2,196,852 | $78,286 | $10,438 | $814,260 | $239,872 | $334,206 |
| 1996 | $2,437,722 | $80,635 | $10,751 | $917,897 | $239,294 | $94,912 |
| 1997 | $2,702,846 | $83,054 | $11,074 | $1,035,252 | $238,839 | ($143,927) |
| 1998 | $2,993,143 | $85,546 | $11,406 | $1,158,689 | $236,563 | ($380,490) |
| 1999 | $3,310,838 | $88,112 | $11,748 | $1,297,649 | $234,455 | ($614,945) |
| 2000 | $3,658,079 | $90,755 | $12,101 | $1,444,224 | $230,918 | ($845,863) |
| 2001 | $4,037,993 | $93,478 | $12,464 | $1,603,975 | $226,942 | ($1,072,805) |
| 2002 | $4,453,171 | $96,282 | $12,838 | $1,782,311 | $223,177 | ($1,295,982) |
| 2003 | $4,906,688 | $99,171 | $13,223 | $1,970,997 | $218,411 | ($1,514,393) |

TABLE A.3 (e) BASE CASE, WITH LOW LABOR COST
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

| | |
|---|---|
| Interest Rate | 13%/year |
| Diesel Escalation Rate | 5%/year |
| Wood Chip Escalation Rate | 3%/year |
| Diesel Utilization Rate | 3.5 kWh/l |
| Chip cost | $31.00/t |
| Diesel cost | $0.320/l (1984) |
| Additional Labour | $30,000/yr |
| Labour Rate Escalation | 3%/year |
| Additional Maintenance | $8,000/yr |
| Maintenance Escalation | 3%/year |
| Mini Hydro | 1,300 MWh/yr |

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $789,466 | $30,000 | $8,000 | $83,617 | $73,997 | $1,919,503 |
| 1987 | $882,071 | $30,900 | $8,240 | $120,743 | $94,560 | $1,824,943 |
| 1988 | $985,074 | $31,827 | $8,487 | $163,459 | $113,285 | $1,711,658 |
| 1989 | $1,067,934 | $32,782 | $8,742 | $202,462 | $124,173 | $1,587,485 |
| 1990 | $1,173,281 | $33,765 | $9,004 | $243,418 | $132,118 | $1,455,367 |
| 1991 | $1,285,849 | $34,778 | $9,274 | $292,054 | $140,279 | $1,315,088 |
| 1992 | $1,405,795 | $35,822 | $9,552 | $346,187 | $147,150 | $1,167,938 |
| 1993 | $1,533,812 | $36,896 | $9,839 | $406,246 | $152,813 | $1,015,125 |
| 1994 | $1,670,222 | $38,003 | $10,134 | $469,051 | $156,140 | $858,985 |
| 1995 | $1,819,097 | $39,143 | $10,438 | $542,121 | $159,702 | $699,282 |
| 1996 | $1,980,819 | $40,317 | $10,751 | $592,700 | $154,516 | $544,767 |
| 1997 | $2,155,200 | $41,527 | $11,074 | $651,094 | $150,211 | $394,555 |
| 1998 | $2,342,067 | $42,773 | $11,406 | $709,205 | $144,794 | $249,761 |
| 1999 | $2,542,232 | $44,056 | $11,748 | $775,839 | $140,174 | $109,585 |
| 2000 | $2,756,359 | $45,378 | $12,101 | $842,448 | $134,700 | ($25,115) |
| 2001 | $2,985,753 | $46,739 | $12,464 | $913,722 | $129,208 | ($154,403) |
| 2002 | $3,231,196 | $48,141 | $12,838 | $994,749 | $124,560 | ($278,963) |
| 2003 | $3,493,718 | $49,585 | $13,223 | $1,076,111 | $119,246 | ($398,210) |

TABLE A.3 (f) BASE CASE, WITH 15% LOWER CAPITAL COST
1250 kW BIOMASS UNIT, CAPITAL COST $1.694475 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,694,475 |
| 1986 | $789,466 | $60,000 | $8,000 | $53,617 | $47,448 | $1,647,027 |
| 1987 | $882,071 | $61,800 | $8,240 | $89,843 | $70,360 | $1,576,666 |
| 1988 | $985,074 | $63,654 | $8,487 | $131,632 | $91,228 | $1,485,439 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $169,680 | $104,068 | $1,381,371 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $209,653 | $113,791 | $1,267,580 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $257,275 | $123,574 | $1,144,005 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $310,365 | $131,924 | $1,012,082 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $369,349 | $138,934 | $873,147 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $431,048 | $143,489 | $729,658 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $502,977 | $148,171 | $581,487 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $552,383 | $144,005 | $437,482 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $609,567 | $140,631 | $296,851 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $666,432 | $136,062 | $160,789 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $731,783 | $132,216 | $28,573 |
| 2000 | $2,756,359 | $90,755 | $12,101 | $797,071 | $127,444 | ($98,871) |
| 2001 | $2,985,753 | $93,478 | $12,464 | $866,983 | $122,675 | ($221,546) |
| 2002 | $3,231,196 | $96,282 | $12,838 | $946,607 | $118,532 | ($340,078) |
| 2003 | $3,493,718 | $99,171 | $13,223 | $1,026,526 | $113,752 | ($453,830) |

TABLE A.3 (g) BEST CASE, PRESENT WORTH OF SAVINGS
1250 kW BIOMASS UNIT, CAPITAL COST $1.694475 M

Interest Rate..... 10%/year
Diesel Escalation Rate..... 7%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $29.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $30,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,694,475 |
| 1986 | $804,503 | $30,000 | $8,000 | $130,698 | $118,817 | $1,575,658 |
| 1987 | $915,993 | $30,900 | $8,240 | $185,728 | $153,494 | $1,422,164 |
| 1988 | $1,042,443 | $31,827 | $8,487 | $249,858 | $187,722 | $1,234,443 |
| 1989 | $1,151,655 | $32,782 | $8,742 | $313,859 | $214,370 | $1,020,072 |
| 1990 | $1,289,360 | $33,765 | $9,004 | $384,186 | $238,550 | $781,523 |
| 1991 | $1,439,981 | $34,778 | $9,274 | $466,731 | $263,457 | $518,066 |
| 1992 | $1,604,291 | $35,822 | $9,552 | $560,043 | $287,391 | $230,675 |
| 1993 | $1,783,725 | $36,896 | $9,839 | $665,175 | $310,309 | ($79,634) |
| 1994 | $1,979,359 | $38,003 | $10,134 | $779,867 | $330,740 | ($410,374) |
| 1995 | $2,196,852 | $39,143 | $10,438 | $911,939 | $351,592 | ($761,966) |
| 1996 | $2,437,722 | $40,317 | $10,751 | $1,018,915 | $357,123 | ($1,119,089) |
| 1997 | $2,702,846 | $41,527 | $11,074 | $1,139,458 | $363,067 | ($1,482,156) |
| 1998 | $2,993,143 | $42,773 | $11,406 | $1,266,454 | $366,847 | ($1,849,002) |
| 1999 | $3,310,838 | $44,056 | $11,748 | $1,408,802 | $370,982 | ($2,219,984) |
| 2000 | $3,658,079 | $45,378 | $12,101 | $1,559,169 | $373,253 | ($2,593,237) |
| 2001 | $4,037,993 | $46,739 | $12,464 | $1,722,745 | $374,920 | ($2,968,156) |
| 2002 | $4,453,171 | $48,141 | $12,838 | $1,904,908 | $376,876 | ($3,345,032) |
| 2003 | $4,906,688 | $49,585 | $13,223 | $2,097,769 | $377,302 | ($3,722,334) |

TABLE A.3 (h) BASE CASE, WITH HIGH INTEREST RATE
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

Interest Rate..... 16%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $789,466 | $60,000 | $8,000 | $53,617 | $46,221 | $1,947,279 |
| 1987 | $882,071 | $61,800 | $8,240 | $89,843 | $66,768 | $1,880,511 |
| 1988 | $985,074 | $63,654 | $8,487 | $131,632 | $84,331 | $1,796,180 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $169,680 | $93,713 | $1,702,467 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $209,653 | $99,819 | $1,602,648 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $257,275 | $105,597 | $1,497,052 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $310,365 | $109,816 | $1,387,235 |
| 1993 | $1,533,912 | $73,792 | $9,839 | $369,349 | $112,661 | $1,274,574 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $431,048 | $113,345 | $1,161,229 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $502,977 | $114,017 | $1,047,212 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $552,383 | $107,945 | $939,268 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $609,567 | $102,689 | $836,578 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $666,432 | $96,784 | $739,794 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $731,783 | $91,616 | $648,179 |
| 2000 | $2,756,359 | $90,755 | $12,101 | $797,071 | $86,025 | $562,153 |
| 2001 | $2,985,753 | $93,478 | $12,464 | $866,983 | $80,665 | $481,489 |
| 2002 | $3,231,196 | $96,282 | $12,838 | $946,607 | $75,925 | $405,564 |
| 2003 | $3,493,718 | $99,171 | $13,223 | $1,026,526 | $70,978 | $334,585 |

TABLE A.3 (i) BASE CASE, WITH HIGH CHIP COST
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $33.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $789,466 | $60,000 | $8,000 | $19,055 | $16,863 | $1,976,637 |
| 1987 | $882,071 | $61,800 | $8,240 | $52,981 | $41,492 | $1,935,145 |
| 1988 | $985,074 | $63,654 | $8,487 | $92,461 | $64,090 | $1,871,065 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $128,025 | $78,520 | $1,792,545 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $165,266 | $89,700 | $1,702,845 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $210,253 | $100,988 | $1,601,857 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $260,635 | $110,786 | $1,491,071 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $316,840 | $119,182 | $1,371,889 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $375,452 | $124,982 | $1,246,906 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $444,442 | $130,927 | $1,115,979 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $491,682 | $128,180 | $987,798 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $546,688 | $126,170 | $861,628 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $601,440 | $122,793 | $738,836 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $664,585 | $120,093 | $618,743 |
| 2000 | $2,756,359 | $90,755 | $12,101 | $727,504 | $116,321 | $502,421 |
| 2001 | $2,985,753 | $93,478 | $12,464 | $794,852 | $112,459 | $389,963 |
| 2002 | $3,231,196 | $96,282 | $12,838 | $872,151 | $109,209 | $280,744 |
| 2003 | $3,493,718 | $99,171 | $13,223 | $949,339 | $105,198 | $175,545 |

TABLE A.3 (j) LOW DIESEL RATE CASE
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 3%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $774,428 | $60,000 | $8,000 | $41,096 | $36,368 | $1,957,132 |
| 1987 | $848,788 | $61,800 | $8,240 | $62,251 | $48,752 | $1,908,380 |
| 1988 | $929,849 | $63,654 | $8,487 | $86,170 | $59,720 | $1,848,659 |
| 1989 | $968,863 | $65,564 | $8,742 | $103,810 | $63,669 | $1,784,990 |
| 1990 | $1,065,716 | $67,531 | $9,004 | $120,342 | $65,317 | $1,719,674 |
| 1991 | $1,145,717 | $69,556 | $9,274 | $141,216 | $67,829 | $1,651,845 |
| 1992 | $1,228,733 | $71,643 | $9,552 | $163,962 | $69,694 | $1,582,151 |
| 1993 | $1,315,090 | $73,792 | $9,839 | $188,693 | $70,979 | $1,511,173 |
| 1994 | $1,404,771 | $76,006 | $10,134 | $211,894 | $70,536 | $1,440,636 |
| 1995 | $1,500,843 | $78,286 | $10,438 | $240,724 | $70,915 | $1,369,722 |
| 1996 | $1,603,142 | $80,635 | $10,751 | $250,247 | $65,239 | $1,304,483 |
| 1997 | $1,711,050 | $83,054 | $11,074 | $264,331 | $60,983 | $1,243,500 |
| 1998 | $1,823,989 | $85,546 | $11,406 | $274,730 | $56,090 | $1,187,410 |
| 1999 | $1,942,165 | $88,112 | $11,748 | $289,999 | $52,396 | $1,135,014 |
| 2000 | $2,065,640 | $90,755 | $12,101 | $301,349 | $48,183 | $1,086,831 |
| 2001 | $2,194,930 | $93,478 | $12,464 | $313,162 | $44,311 | $1,042,520 |
| 2002 | $2,330,118 | $96,282 | $12,838 | $330,365 | $41,368 | $1,001,152 |
| 2003 | $2,471,443 | $99,171 | $13,223 | $343,206 | $38,031 | $963,121 |

TABLE A.3 (k) WORST CASE, PRESENT WORTH OF SAVINGS
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

Interest Rate..... 16%/year
Diesel Escalation Rate..... 3%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $33.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $774,428 | $60,000 | $8,000 | $6,535 | $5,634 | $1,987,866 |
| 1987 | $848,788 | $61,800 | $8,240 | $25,389 | $18,868 | $1,968,998 |
| 1988 | $929,849 | $63,654 | $8,487 | $46,999 | $30,110 | $1,938,888 |
| 1989 | $988,863 | $65,564 | $8,742 | $62,156 | $34,328 | $1,904,560 |
| 1990 | $1,065,716 | $67,531 | $9,004 | $75,955 | $36,163 | $1,868,397 |
| 1991 | $1,145,717 | $69,556 | $9,274 | $94,194 | $38,661 | $1,829,736 |
| 1992 | $1,228,733 | $71,643 | $9,552 | $114,232 | $40,418 | $1,789,317 |
| 1993 | $1,315,090 | $73,792 | $9,839 | $136,183 | $41,539 | $1,747,778 |
| 1994 | $1,404,771 | $76,006 | $10,134 | $156,299 | $41,099 | $1,706,679 |
| 1995 | $1,500,843 | $78,286 | $10,438 | $182,189 | $41,299 | $1,665,379 |
| 1996 | $1,603,142 | $80,635 | $10,751 | $189,547 | $37,041 | $1,628,339 |
| 1997 | $1,711,050 | $83,054 | $11,074 | $201,651 | $33,971 | $1,594,368 |
| 1998 | $1,823,989 | $85,546 | $11,406 | $209,738 | $30,460 | $1,563,909 |
| 1999 | $1,942,165 | $88,112 | $11,748 | $222,901 | $27,906 | $1,536,002 |
| 2000 | $2,065,640 | $90,755 | $12,101 | $231,783 | $25,016 | $1,510,987 |
| 2001 | $2,194,930 | $93,478 | $12,464 | $241,032 | $22,426 | $1,488,561 |
| 2002 | $2,330,118 | $96,282 | $12,838 | $255,909 | $20,526 | $1,468,035 |
| 2003 | $2,471,443 | $99,171 | $13,223 | $266,020 | $18,394 | $1,449,642 |

TABLE A.3 (1) BASE CASE, WITH STEAM ENGINE
1250 kW BIOMASS UNIT, CAPITAL COST $2.0335 M

| | | |
|---|---|---|
| Interest Rate | 13%/year | |
| Diesel Escalation Rate | 5%/year | |
| Wood Chip Escalation Rate | 3%/year | |
| Diesel Utilization Rate | 3.5 kWh/l | |
| Chip cost | $31.00/t | |
| Diesel cost | $0.320/l | (1984) |
| Additional Labour | $60,000/yr | |
| Labour Rate Escalation | 3%/year | |
| Additional Maintenance | $0/yr | |
| Maintenance Escalation | 3%/year | |
| Mini Hydro | 1,300 MWh/yr | |

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $2,033,500 |
| 1986 | $789,466 | $60,000 | $0 | $71,744 | $63,490 | $1,970,010 |
| 1987 | $882,071 | $61,800 | $0 | $111,413 | $87,252 | $1,882,758 |
| 1988 | $985,074 | $63,654 | $0 | $157,098 | $108,877 | $1,773,881 |
| 1989 | $1,067,934 | $65,564 | $0 | $198,743 | $121,893 | $1,651,988 |
| 1990 | $1,173,281 | $67,531 | $0 | $242,521 | $131,631 | $1,520,357 |
| 1991 | $1,285,849 | $69,556 | $0 | $294,565 | $141,485 | $1,378,872 |
| 1992 | $1,405,795 | $71,643 | $0 | $352,544 | $149,852 | $1,229,020 |
| 1993 | $1,533,812 | $73,792 | $0 | $416,920 | $156.828 | $1,072,191 |
| 1994 | $1,670,222 | $76,006 | $0 | $484,304 | $161,218 | $910,974 |
| 1995 | $1,819,097 | $78,286 | $0 | $562,734 | $165,775 | $745,199 |
| 1996 | $1,980,819 | $80,635 | $0 | $616,765 | $160,789 | $584,410 |
| 1997 | $2,155,200 | $83,054 | $0 | $679,301 | $156,719 | $427,691 |
| 1998 | $2,342,067 | $85,546 | $0 | $741,440 | $151,376 | $276,315 |
| 1999 | $2,542,232 | $88,112 | $0 | $812,870 | $146,867 | $129,449 |
| 2000 | $2,756,359 | $90,755 | $0 | $884,165 | $141,370 | ($11,921) |
| 2001 | $2.985,753 | $93.478 | $0 | $960,572 | $135,917 | ($147,838) |
| 2002 | $3,231,196 | $96,282 | $0 | $1,047,431 | $131,157 | ($278,996) |
| 2003 | $3,493,718 | $99,171 | $0 | $1,134,621 | $125,730 | ($404,726) |

TABLE A.3 (m) BASE CASE, WITH NEW DIESEL IN 1995
1250 kW BIOMASS UNIT, CAPITAL COST $1.9935 M

| | | |
|---|---|---|
| Interest Rate | 13%/year | |
| Diesel Escalation Rate | 5%/year | |
| Wood Chip Escalation Rate | 3%/year | |
| Diesel Utilization Rate | 3.5 kWh/l | |
| Chip cost | $31.00/t | |
| Diesel cost | $0.320/l | (1984) |
| Additional Labour | $60,000/yr | |
| Labour Rate Escalation | 3%/year | |
| Additional Maintenance | $8,000/yr | |
| Maintenance Escalation | 3%/year | |
| Mini Hydro | 1,300 MWh/yr | |

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,993,500 |
| 1986 | $789,466 | $60,000 | $8,000 | $53,617 | $47,448 | $1,946,052 |
| 1987 | $882,071 | $61,800 | $8,240 | $89,843 | $70,360 | $1,875,691 |
| 1988 | $985,074 | $63,654 | $8,487 | $131,632 | $91,228 | $1,784,464 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $169,680 | $104,068 | $1,680,396 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $209,653 | $113,791 | $1,566,605 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $257,275 | $123,574 | $1,443,030 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $310,365 | $131,924 | $1,311,107 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $369,349 | $138,934 | $1,172,172 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $431,048 | $143,489 | $1,028,683 |
| 1995 | $2,859,377 | $78,286 | $10,438 | $1,543,257 | $454,626 | $574,057 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $552,383 | $144,005 | $430,052 |
| 1997 | $2,155,200 | $83,054 | $11,074 | $609,567 | $140,631 | $289,422 |
| 1998 | $2,342,067 | $85,546 | $11,406 | $666,432 | $136,062 | $153,360 |
| 1999 | $2,542,232 | $88,112 | $11,748 | $731,783 | $132,216 | $21,144 |
| 2000 | $2,756,359 | $90,755 | $12,101 | $797,071 | $127,444 | ($105,300) |
| 2001 | $2,985,753 | $93,476 | $12,464 | $866,983 | $122,675 | ($228,975) |
| 2002 | $3,231,196 | $96,282 | $12,838 | $946,607 | $118,532 | ($347,507) |
| 2003 | $3,493,718 | $99,171 | $13,223 | $1,026,526 | $113,752 | ($461,259) |

TABLE A.3 (n) BASE CASE, WITH 40% LOWER CAPITAL COST
1250 kW BIOMASS UNIT, CAPITAL COST $1.1961 M

Interest Rate..... 13%/year
Diesel Escalation Rate..... 5%/year
Wood Chip Escalation Rate..... 3%/year
Diesel Utilization Rate..... 3.5 kWh/l
Chip cost..... $31.00/t
Diesel cost..... $0.320/l (1984)
Additional Labour..... $60,000/yr
Labour Rate Escalation..... 3%/year
Additional Maintenance ..... $8,000/yr
Maintenance Escalation ..... 3%/year
Mini Hydro ..... 1,300 MWh/yr

| YEAR | COST DIESEL ONLY SYSTEM | EXTRA WAGES | EXTRA MAINT. | SAVINGS | PRESENT WORTH | CUMULATIVE PRESENT WORTH |
|---|---|---|---|---|---|---|
| 1985 | $705,696 | | | $0 | $0 | $1,196,100 |
| 1986 | $789,466 | $60,000 | $8,000 | $53,617 | $47,448 | $1,148,652 |
| 1987 | $882,071 | $61,800 | $8,240 | $89,843 | $70,360 | $1,078,291 |
| 1988 | $985,074 | $63,654 | $8,487 | $131,632 | $91,228 | $987,064 |
| 1989 | $1,067,934 | $65,564 | $8,742 | $169,680 | $104,068 | $882,996 |
| 1990 | $1,173,281 | $67,531 | $9,004 | $209,653 | $113,791 | $769,205 |
| 1991 | $1,285,849 | $69,556 | $9,274 | $257,275 | $123,574 | $645,630 |
| 1992 | $1,405,795 | $71,643 | $9,552 | $310,365 | $131,924 | $513,707 |
| 1993 | $1,533,812 | $73,792 | $9,839 | $369,349 | $138,934 | $374,772 |
| 1994 | $1,670,222 | $76,006 | $10,134 | $431,048 | $143,489 | $231,283 |
| 1995 | $1,819,097 | $78,286 | $10,438 | $502,977 | $148,171 | $83,112 |
| 1996 | $1,980,819 | $80,635 | $10,751 | $552,383 | $144,005 | ($60,893) |
| 1997 | $2,155,200 | $83,054 | $11,074 | $609,567 | $140,631 | ($201,524) |
| 1998 | $2,342,067 | $85,546 | $11,406 | $666,432 | $136,062 | ($337,586) |
| 1999 | $2,542,232 | $88,112 | $11,748 | $731,783 | $132,216 | ($469,802) |
| 2000 | $2,756,359 | $90,755 | $12,101 | $797,071 | $127,444 | ($597,246) |
| 2001 | $2,985,753 | $93,478 | $12,464 | $866,983 | $122,675 | ($719,921) |
| 2002 | $3,231,196 | $96,282 | $12,838 | $946,607 | $118,532 | ($838,453) |
| 2003 | $3,493,718 | $99,171 | $13,223 | $1,026,526 | $113,752 | ($952,205) |

# Appendix B
# Manufacturers Quotations

TRANE1A LCR

ACRES SNF

MAY 10, 1984
FILE NO. P7150.00
SEQ. NO. 84-774

ATTN: MR. D. SHELDON
FROM: MAURICE MILLS
SUBJ: TURBO GENERATOR SETS

ACRES CONSULTING SERVICES LIMITED ARE PRESENTLY CARRYING OUT A STUDY TO REPLACE DIESEL GENERATED POWER WITH STEAM TURBINES RUN BY WOOD FIRED BOILERS. WE ARE TRYING TO DECIDE ON SIZE OF UNIT REQUIRED TO MEET ELECTRICAL DEMANDS OF SEVERAL TOWNS NOW BEING SUPPLIED BY DIESEL POWER. WE HAVE A PROBLEM WITH A LOW BASE LOAD AND A RELATIVELY HIGH PEAK AT LUNCH AND SUPPER TIME - 72 PERCENT OF TOTAL LOAD IS DOMESTIC WITH NO ELECTRIC HEAT. COULD YOU ADVISE WHAT IS THE EFFICIENCY LOSS WHEN THE UNIT IS OPERATED BELOW CAPACITY BY VARIOUS PERCENTAGES. AN EXAMPLE - WE HAVE A BASE LOAD OF 400 KW, HOWEVER, WOULD NEED A 2000KW UNIT TO MEET ALL REQUIREMENTS.

I WILL BE REQUESTING BUDGET PRICE FOR VARIOUS SIZES OF UNITS SHORTLY, ALSO STEAM REQUIREMENTS FOR UNITS.

REGARDS
MAURICE MILLS

TRANE1A LCR

ACRES SNF

May 18, 1984
P7150.00

Trane-Murray
c/o The Trane Company
3600 Pamnele Creek Road
LaCross
Wisconsin 54601
U.S.A.

Attention: Mr. D. Sheldon

Dear Sir:

Acres Consulting Services Limited has been retained by the Federal Department of Energy Mines and Resources to carry out a feasibility study into the replacement of diesel generated electrical power in the three remote Newfoundland communities of Main Brook, Roddickton, and Croque with a steam produced electricity. The system would be based on the burning of wood waste to produce steam to run a steam turbine and generator. The installation would also act as a demonstration project for other diesel generated power sites and industry in general.

Due to the nature of the electrical load, (mainly residential), we are encountering a problem with a high peak load but a relatively low base load, to determine the optimum size for the unit. We would like to know the following information for the various sizes shown.

ACRES CONSULTING SERVICES LIMITED
44 Torbay Road, St. John's, Newfoundland A1A 2G4
Telephone 709-754-1710
Telex 016-4118
Toronto, Burlington, Calgary, Halifax, Niagara Falls, St. John's, Vancouver, Winnipeg

File - 2

Steam Requirement lb/hr at Various Power Outputs

(See Note 2)

| | Size (Kw) Unit | 90% | 80% | 70% | 60% | 50% | 40% | 30% | 20% |
|---|---|---|---|---|---|---|---|---|---|
| Croque | 50 | | | | | | | | |
| | 100 | | | | | | | | |
| Main Brook | 200 | | | | | | | | |
| | 300 | | | | | | | | |
| | 400 | | | | | | | | |
| Roddickton | 600 | | | | | | | | |
| | 1250 | | | | | | | | |
| | 1750 | | | | | | | | |
| | 2500 | | | | | | | | |

Note: (1) Please indicate the absolute minimum power output of each unit as the operation will require large fluctuations in power demand with efficiency not a major factor.

(2) Steam available at turbine
230 PSIG (Steam quality will be sent by telex)

For estimating purposes, would you please provide a budget price as follows for each size of unit shown.

- Price in U.S. Dollars (1984);
- F.O.B. LaCross Wisconsin (indicate shipping wt);
- Custom and import duties to be shown extra;
- Price to be for complete package including turbine generator and condensator. The boiler manufacturer will provide steam to the unit and accept return water back from the unit;

File - 3

- Cost per day for start up and trial runs. We will include travel and accommodation costs;
- Cost estimate for spare parts.

If you need any further clarification on any points, please contact either myself or Ms. Susan Richter at our St. John's office.

Your early attention to this matter would be appreciated.

Yours very truly,

Maurice S. Mills
Regional Manager

MSM:jak

ACRES



May 24, 1984
P7150.00

Wellons Inc.
P.O. Box 381
Sherwood
Oregon 97140
U.S.A.

Dear Sir:

Acres Consulting Services Limited has been retained by the Federal Department of Energy Mines and Resources to carry out a feasibility study into the replacement of diesel generated electrical power in the three remote Newfoundland communities of Main Brook, Roddickton, and Croque with steam produced electricity. The system would be based on the burning of wood waste to produce steam to run a steam turbine and generator. The installation would also act as a demonstration project for other diesel generated power sites and industry in general.

Due to the nature of the electrical load, (mainly residential), we are encountering a problem with a high peak load but a relatively low base load, to determine the optimum size for the unit. We would like to know the following information for the various sizes shown.

ACRES CONSULTING SERVICES LIMITED
44 Torbay Road, St. John's, Newfoundland A1A 2G4
Telephone 709-754-1710
Telex 016-4118
Toronto, Burlington, Calgary, Halifax, Niagara Falls, St. John's, Vancouver, Winnipeg

File - 2

**Steam Requirement lb/hr at Various Power Outputs**

(See Note 2)

| | Size (Kw) Unit | 90% | 80% | 70% | 60% | 50% | 40% | 30% | 20% |
|---|---|---|---|---|---|---|---|---|---|
| Croque | 50 | | | | | | | | |
| | 100 | | | | | | | | |
| Main Brook | 200 | | | | | | | | |
| | 300 | | | | | | | | |
| | 400 | | | | | | | | |
| Roddickton | 600 | | | | | | | | |
| | 1250 | | | | | | | | |
| | 1750 | | | | | | | | |
| | 2500 | | | | | | | | |

Note: (1) Please indicate the absolute minimum power output of each unit as the operation will require large fluctuations in power demand with efficiency not a major factor.

(2) Steam available at turbine
230 PSIG (Steam quality will be sent by telex)

This request for budget pricing is for the generation system only and should not include the wood burning boiler.

For estimating purposes, would you please provide a budget price as follows for each size of unit shown.

- Price in U.S. Dollars (1984);
- F.O.B. Sherwood Oregon (indicate shipping wt);
- Custom and import duties to be shown extra;

File - 3

- Price to be for complete package including turbine generator and condensator. The boiler manufacturer will provide steam to the unit and accept return water back from the unit;
- Cost per day for start up and trial runs. We will include travel and accommodation costs;
- Cost estimate for spare parts.

If you need any further clarification on any points, please contact either myself or Ms. Susan Richter at our St. John's office.

Your early attention to this matter would be appreciated.

Yours very truly,

Susan Richter

for Maurice S. Mills
Regional Manager

MSM:jak

ACRES SNF

BELL STMI SEAF

MAY 31, 1984
ATTN: MAURICE MILLS

RE: YOUR INQUIRY

STEAM QUALITY IS 98 PER CENT , APPROX. STEAM TEMP AT 230 PSIG IS 399 DEGREES F.

RE: 15000 LB/HR BOILER
150 PSIG DESIGN PRESSURE APPROX. WEIGHT 50,000LBS

REGARDS
C B SMITH
ROBERT BELL INDUSTRIES LIMITED
SEAFORTH, ONTARIO

BELL STMI SEAF

ACRES SNF

Doug Sheldon
1-603-757-3077

TRANE1A LCR

ACRES SNF

IS DAVE SHELDON IN THIS OFFICE?

XES
ES

JUNE 1, 1984
FILE NO. P7150.00
SEQ. NO. 84-813

ATTN: DAVE SHELDON
FROM: MAURICE MILLS

RE OUR LETTER OF MAY 24, 1984

STEAM QUALITY IS 98 PERCENT. APPROXIMATE STEAM TEMP AT 230 PSIG IS 399 DEGREES F.

REGARDS
MAURICE MILLS

TRANE1A LCR

ACRES SNF

ACRES SNF

EASYLINK 351434A001 21JUN84 12:09/12:17 EST
FROM: TLX 757325 MURRAY UD
MURRAY TURBOMACHINERY CORP
TO: 0164118



TO: ACRES CONSULTING
ST. JOHN'S / NEWFOUNDLAND

ATTN: MR. GILL

FROM: JUDI SNYDER
MURRAY TURBOMACHINERY

DATE: JUNE 21, 1984

SUBJ: FEDERAL DEPARTMENT OF ENERGY
MURRAY REF: 6226

REUR MAY 18 REQUEST TO TRANE-MURRAY. TRANE-MURRAY IS NOW MURRAY TURBOMACHINERY LOCATED IN BURLINGTON IOWA.

TURBINE GENERATOR SELECTIONS AS FOLLOW USING STEAM AT 230 PSIG, 98 PRECENT QUALITY INLET AND 4+ HGA EXHAUST.

| KW | RATE/KW/HR | US DOLLARS FOB BURLINGTON, IA |
|---|---|---|
| 50 | 30.5 | □123,000 |
| 100 | 27.9 | □125,000 |
| 200 | 23.0 | □175,000 |
| 300 | 21.1 | □179,000 |
| 400 | 20.1 | □181,000 |
| 600 | 18.9 | □214,000 |
| 1250 | 18.3 | □230,000 |
| 1750 | 17.9 | □284,000 |
| 2500 | 17.4 | □343,000 |

PACKAGE DOES NOT INCLUDE CONDENSER. WILL CONFIRM WITH COMPLETE INFORMATION THROUGH OUR REPRESENTATIVE IN YOUR AREA - AFFILIATED ENGINEERING EQUIPMENT, LTD.

CC: AFFILIATED ENGINEERING
QUEBEC, CANADA
ATTN: GRAHAM KENNEDY

DAVE SHELDON

MMMM

ACRES SNF

OVMTOOO*
IRCTERY WSOR

ACRES SNF

TERRY STEAM TURBINES
WINDSOR CONN USA

FROM: MAURICE MILLS - ACRES CONSULTING SERVICES LIMITED
SEQ NO 84-860
FILE NO P7150.00

ACRES CONSULTING SERVICES LIMITED HAS BEEN RETAINED BY THE FEDERAL DEPARTMENT OF ENERGY MINES AND RESOURCES TO CARRY OUT A FEASIBILITY STUDY INTO THE REPLACEMENT OF DIESEL GENERATED ELECTRICAL POWER IN THE THREE REMOTE NEWFOUNDLAND COMMUNITIES OF MAIN BROOK, RODDICKTON, AND CROQUE WITH STEAM PRODUCED ELECTRICITY. THE SYSTEM WOULD BE BASED ON THE BURNING OF WOOD WASTE TO PRODUCE STEAM TO RUN A STEAM TURBINE AND GENERATOR. THE INSTALLATION WOULD ALSO ACT AS A DEMONSTRATION PROJECT FOR OTHER DIESEL GENERATED POWER SITES AND INDUSTRY IN GENERAL.

DUE TO THE NATURE OF THE ELECTRICAL LOAD, (MAINLY RESIDENTIAL), WE ARE ENCOUNTERING A PROBLEM WITH A HIGH PEAK LOAD BUT A RELATIVELY LOW BASE LOAD, TO DETERMINE THE OPTIMUM SIZE FOR THE UNIT. WE WOULD LIKE TO KNOW THE FOLLOWING INFORMATION FOR THE VARIOUS SIZES SHOWN.

| | | STEAM REQUIREMENT LB/HR AT VARIOUS POWER OUTPUTS (SEE NOTE 2) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | SIZE (KW) UNIT | 90 PERCENT | 80 PER | 70 PC | 60 PC | 50 | 40 | 30 | 20 |
| CROQUE | 100 | | | | | | | | |
| MAIN BROOK | 200 | | | | | | | | |
| | 400 | | | | | | | | |
| RODDICKTON | 600 | | | | | | | | |
| | 1000 | | | | | | | | |
| | 1500 | | | | | | | | |
| | 2000 | | | | | | | | |

PC = PERCENT

NOTE: (1) PLEASE INDICATE THE ABSOLUTE MINIMUM POWER OUTPUT OF EACH UNIT AS THE OPERATION WILL REQUIRE LARGE FLUCTUATIONS IN POWER DEMAND WITH EFFICIENCY NOT A MAJOR FACTOR. 125

(2) STEAM AVAILABLE AT TURBINE
230 PSIG (98 PERCENT QUALITY 399 DEGREES F)

THIS REQUEST FOR BUDGET PRICING IS FOR THE GENERATION SYSTEM ONLY AND SHOULD NOT INCLUDE THE WOOD BURNING BOILER.

FOR ESTIMATING PURPOSES, WOULD YOU PLEASE PROVIDE A BUDGET PRICE AS FOLLOWS FOR EACH SIZE OF UNIT SHOWN.

- PRICE IN U.S. DOLLARS (1984):
- F.O.B. - YOUR PLANT
- EXPECTED CUSTOM AND IMPORT DUTIES TO BE SHOWN EXTRA
- PRICE TO BE FOR COMPLETE PACKAGE INCLUDING TURBINE GENERATOR AND CONDENSATOR. THE BOILER MANUFACTURER WILL PROVIDE STEAM TO THE UNIT AND ACCEPT RETURN WATER BACK FROM THE UNIT,
- COST PER DAY FOR START UP AND TRIAL RUNS. WE WILL INCLUDE TRAVEL AND ACCOMMODATION COSTS.

IF YOU NEED ANY FURTHER CLARIFICATION ON ANY POINTS, PLEASE CONTACT M. MILLS AT OUR ST. JOHN'S OFFICE.

REGARDS
MAURICE MILLS

IRCTERY WSOR

ACRES SNF
V

GA P=LS

JULY 12, 1984
FILE NO. P7150.00
SEQ. NO. 84-859

ATTN: TURBODYNE - MCGRAW EDISON CO - MR. TUCKER
FROM: MAURICE MILLS - ACRES CONSULTING SERVICES LIMITED

FURTHER TO OUR CONVERSATION OF JLY 11/84, I WOULD LIKE TO PROVIDE THE FOLLOWING INFO AND REQUEST INFORMATION.

ACRES CONSULTING SERVICES LIMITED HAS BEEN RETAINED BY THE FEDERAL DEPARTMENT OF ENERGY MINES AND RESOURCES TO CARRY OUT A FEASIBILITY STUDY INTO THE REPLACEMENT OF DIESEL GENERATED ELECTRICAL POWER IN THE THREE REMOTE NEWFOUNDLAND COMMUNITIES OF MAIN BROOK, RODDICKTON, AND CROQUE WITH STEAM PRODUCED ELECTRICITY. THE SYSTEM WOULD BE BASED ON THE BURNING OF WOOD WASTE TO PRODUCE STEAM TO RUN A STEAM TURBINE AND GENERATOR. THE INSTALLATION WOULD ALSO ACT AS A DEMONSTRATION PROJECT FOR OTHER DIESEL GENERATED POWER SITES AND INDUSTRY IN GENERAL.

DUE TO THE NATURE OF THE ELECTRICAL LOAD, (MAINLY RESIDENTIAL), WE ARE ENCOUNTERING A PROBLEM WITH A HIGH PEAK LOAD BUT A RELATIVELY LOW BASE LOAD, TO DETERMINE THE OPTIMUM SIZE FOR THE UNIT. WE WOULD LIKE TO KNOW THE FOLLOWING INFORMATION FOR THE VARIOUS SIZES SHOWN.

STEAM REQUIREMENT LB/HR AT VARIOUS POWER OUTPUTS
(SEE NOTE 2)

| | SIZE (KW) UNIT | 90 PERCENT | 80 PER | 70 PC | 60 PC | 50 | 40 | 30 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| CROQUE | 100 | | | | | | | | |
| MAIN BROOK | 200 | | | | | | | | |
| | 400 | | | | | | | | |
| RODDICKTON | 600 | | | | | | | | |
| | 1000 | | | | | | | | |
| | 1500 | | | | | | | | |
| | 2000 | | | | | | | | |

NOTE: (1) PLEASE INDICATE THE ABSOLUTE MINIMUM POWER OUTPUT OF EACH UNIT AS THE OPERATION WILL REQUIRE LARGE FLUCTUATIONS IN POWER DEMAND WITH EFFICIENCY NOT A MAJOR FACTOR.

(2) STEAM AVAILABLE AT TURBINE
230 PSIG (98 PERCENT QUALITY 399 DEGREES F)

THIS REQUEST FOR BUDGET PRICING IS FOR THE GENERATION SYSTEM ONLY AND SHOULD NOT INCLUDE THE WOOD BURNING BOILER.

FOR ESTIMATING PURPOSES, WOULD YOU PLEASE PROVIDE A BUDGET PRICE AS FOLLOWS FOR EACH SIZE OF UNIT SHOWN.

- PRICE IN U.S. DOLLARS (1984):
- F.O.B. - YOUR PLANT
- EXPECTED CUSTOM AND IMPORT DUTIES TO BE SHOWN EXTRA
- PRICE TO BE FOR COMPLETE PACKAGE INCLUDING TURBINE GENERATOR AND CONDENSATOR. THE BOILER MANUFACTURER WILL PROVIDE STEAM TO THE UNIT AND ACCEPT RETURN WATER BACK FROM THE UNIT.
- COST PER DAY FOR START UP AND TRIAL RUNS. WE WILL INCLUDE TRAVEL AND ACCOMMODATION COSTS.

IF YOU NEED ANY FURTHER CLARIFICATION ON ANY POINTS, PLEASE CONTACT M. MILLS AT OUR ST. JOHN'S OFFICE.

REGARDS
MAURICE MILLS

■◆
6854321WG TURBO

ACRES SNF
M

128

tlx NO.- 06-961280
He is out of town. Secretary will forward to Mr. Alan Winfield

GECCANADA MSGA ,Ontario

ACRES SNF

JULY 31, 1984
FILE NO. P7150.00
SEQ. NO. 84-884

ATTN: A. HUNTINGTON
FROM: S. RICHTER -ACRES
SUBJ: BROTHERHOOD TURBINES

WE ARE CONSIDERING THE FEASIBILITY OF REPLACING REMOTE COMMUNITY DIESEL GENERATING SYSTEMS WITH WOODCHIP BURNING BOILERS SUPPLY TURBINE GENERATORS. WE ARE INTERESTED IN THE BROTHERHOOD PACKAGED COMBINED TURBINE GENERATOR CONDENSING PLANT.

COULD YOU SUPPLY BUDGET PRICES FOR THE FOLLOWING SIZES OF UNIT.

600 KW
1250 KW
1750 KW
2500 KW

REGARDS
S. RICHTER
ACRES CONSULTING SERVICES LIMITED
ST. JOHN'S, NEWFOUNDLAND
A1A 1G4
709-754-1710
TLX 016-4118

P7150



# LES ÉQUIPEMENTS D'INGENIERIE A.E.
# AFFILIATED ENGINEERING EQUIPMENT

• DIVISION DES INDUSTRIES WAJAX LIMITEE
• 6555 Côte de Liesse, Montréal, Qué., H4T 1E6
• TEL.: (514) 342-9570 – TELEX: 05-824643

RECEIVED
JUL 17 1984
Acres Consulting Services Ltd.

July 13th, 1984

ACRES CONSULTING SERVICES LTD.
44, Torbay Road.
St. John's, Newfoundland
A1A 2G4

ATTENTION: Mr. M. S. Mills. Regional Manager

RE: FEASIBILITY STUDY TO REPLACE DIESEL GENERATORS WITH STEAM TURBINE GENERATOR P7150.00

Dear Mr. Mills,

In reference to your May 18th, 1984 letter to our principals TRANE-MURRAY requesting technical data and prices on their Steam Turbine Generating Sets.

Our apologies for not responding to your letter earlier, due in part to the changes caused by the amalgamation of the COPPUS and MURRAY organisations and its consequent temporary disruptions.

This letter confirms the prices given in MURRAY'S telex of June 21st, 1984 and in addition, also find attached one page of data and pricing on the nine (9) selections made by Murry.

Please be advised that all the units selected can operate from zero to full load.

Thank you for your interest in our equipment, Mr. Mills, and now look forward to hearing from you if we can be of any further assistance.

Yours very truly,

AFFILIATED ENGINEERING EQUIPMENT

R. E. Timmins
Sales Manager

RET/jp

Encl.

RECEIVED
JUL 17 1984
Acres Consulting Services Ltd.

1. DESCRIPTION

COPPUS MURRAY Steam Turbine Generating Sets equipped as follows:-

Wooward Type UG, NEMA of class D oil relay governor with motor operated speed synchronizing device.
Separate emergency overspeed system.
Trip valve per tabulation.
Removable steam strainer.
Stainless steel nozzles and blading.
Sentinal warning valve mounted on the exhaust casing.
Carbon ring gland and interstage seals.
Tilting pad type thrust bearing.
Solenoid trip mechanism.
Low oil pressure trip.
Vacuum breaker.
Electric tachometer.
Gaugeboard with three steampressure gauges and the tachometer indicator mounted theron.
Insulation and lagging
Pressure lubrication system for turbine or turbine and auxiliary pump, single cooler, single filter, three minute minimum retention time tank, pressure gauges, relief valves, thermometers at the cooler inlet and outlet and the turbine bearing drain lines with seamless carbon steel piping within the confines of the unit.
High speed coupling with spacer and coupling guard.
Low speed coupling with spacer and coupling guard for Main Brook and Roddickton.
Horizontal offset reduction gear for Main Brook and Roddickton.
Three phase, sixty cycle synchronous generator with voltage regulator.
Complete unit mounted on structual steel baseplate.

2. TERMS AND CONDITIONS.

1. Prices are F.O.B. Burlington, Iowa.
2. Prices are in U.S. funds, duties and brokerage not included.
3. Prices do not include the condenser.
4. Spare parts are not included in our prices.
5. Terms of payment to be discussed.
6. Prices are budget only and are subject to revision.
7. Rate for a service engineer (July 1984) is $512.00 per 8 hour day, plus travel and living expenses.

R. E. Timmins
Sales Manager

RET/jp

Steam Conditions: 230 psig, 98% quality inlet and 4" HgA exhaust.

| Location | CROQUE | | MAIN BROOK | | | RIDDICKTON | | | |
|---|---|---|---|---|---|---|---|---|---|
| Rating | 50 KW | 100 KW | 200 KW | 300 KW | 400 KW | 600 KW | 1250 KW | 1750 KW | 2500 KW |
| Turbine Frame | K2G4 | K2G4 | K2G4 | K2G4 | K2G4 | KG8 | KG7 | KD6 | KD6 |
| Turbine RPM | 3600 | 3600 | 6000 | 6000 | 6000 | 6000 | 6000 | 5000 | 5000 |
| Gear RPM | ---- | ---- | 1800 | 1800 | 1800 | 1800 | 1800 | 1800 | 1800 |
| Rate/KW/HR | 30.5# | 27.9# | 23.0# | 21.1# | 20.1# | 18.9# | 18.3# | 17.9# | 17.4# |
| Steam Inlet | 4" LH | 4" LH | 3" LH | 3" LH | 3" LH | 3" LH | 4" LH | 6" LH | 6" LH |
| Exhaust | 10" Side | 10" Side | 20" Vert. | 20" Vert. | 20" Vert. | 20" Vert. | 24" Vert. | 24" Vert. | 30" Vert. |
| Weight # | 8,500# | 8,500# | 11,000# | 12,000# | 13,000# | 18,000# | 23,000# | 32,000# | 41,000# |
| US Dollars Budget Net | $123,000 | $125,000 | $175,000 | $179,000 | $181,000 | $214,000 | $230,000 | $284,000 | $343,000 |
| Ship Weeks | 22 Weeks | 22 Weeks | 24 Weeks | 24 Weeks | 24 Weeks | 24 Weeks | 24 Weeks | 24 Weeks | 24 Weeks |

Note: Turbines for Croque include a butterfly trip valve

Turbines for Main Brook and Riddickton include trip and throttle valve

File - 2

Steam Requirement lb/hr at Various Power Outputs

(See Note 2)

| | Size (Kw) Unit | 90% | 80% | 70% | 60% | 50% | 40% | 30% | 20% |
|---|---|---|---|---|---|---|---|---|---|
| Croque | 50 | 1407 | 1280 | 1160 | 1025 | 920 | 800 | 660 | 510 |
| | 100 | 2585 | 2328 | 2080 | 1910 | 1617 | 1417 | 1165 | 780 |
| Main Brook | 200 | 4250 | 3864 | 3450 | 3067 | 2669 | 2244 | 1865 | 1430 |
| | 300 | 5787 | 5275 | 4645 | 4212 | 3564 | 2993 | 2470 | 1880 |
| | 400 | 7371 | 6697 | 5913 | 5290 | 4524 | 3830 | 3150 | 2364 |
| Roddickton | 600 | 10253 | 9333 | 8326 | 7280 | 6264 | 5325 | 4215 | 3276 |
| | 1250 | 20835 | 18850 | 16525 | 14526 | 12285 | 10439 | 8154 | 6290 |
| | 1750 | 28575 | 25700 | 22855 | 20216 | 17125 | 14484 | 11627 | 8684 |
| | 2500 | 39432 | 35488 | 31595 | 27690 | 23696 | 19865 | 15768 | 12045 |

Note: (1) Please indicate the absolute minimum power output of each unit as the operation will require large fluctuations in power demand with efficiency not a major factor.

(2) Steam available at turbine
230 PSIG (Steam quality will be sent by telex)

For estimating purposes, would you please provide a budget price as follows for each size of unit shown.

- Price in U.S. Dollars (1984);
- F.O.B. LaCross Wisconsin (indicate shipping wt);
- Custom and import duties to be shown extra;
- Price to be for complete package including turbine generator and condensator. The boiler manufacturer will provide steam to the unit and accept return water back from the unit;

ACRES SNF

ACRES NFS

NR 00015 840831 1156

CHARGE NO. P715000

ACRES CONSULTING SERVICES LTD
ST. JOHN'S, NEWFOUNDLAND AUG 31/84 P7150.00

ATTN - M. MILLS

RE - COOLING TOWER FOR RODDINGTON

SUGGEST YOU USE FOLLOWING

1 - MARLEY MODEL 452-202
2545 USGPM - 22 DEG F COOLING RANGE
SUPPLY FROM TOWER 80 DEG F
LOCAL AMBIENT WET BULB 63 DEG F
2 TOWER UNITS
2 MOTORS 2 SPEED, 25 HP EACH COMPLETE WITH STAIRWAY, ETC
MATERIAL FOB NFLD 68,145 DOLLARS
ERECTION 34,275

TOTAL 102,420 DOLLARS + EST TRANS 20,000 say $ 125,000

2 - OVERALL SIZE 32 FT LONG BY 27 FT WIDE BY 19 FT HIGH PLUS BASIN.

3 - ADD CONCRETE BASIN APPROX. 32 FT LONG BY 21 FT WIDE BY 4 FT DEEP.

4 - ADD PIPING AND PUMPS FROM TOWER TO CONDENSER TO TOWER TOP.

REGARDS

ORGAUBE
ACRES - NFALLS

ACRES SNF

ACRES NFS

ACRES

# Memo Re Telephone Call



JOB No. P7150

DATE June 23/84

FILE No.

FROM (Originator) P. Allen

Company NORTHFAB CANADA LTD

TO M. Webb

Company ACRES CONSULTANTS

SUBJECT Boiler Cost F. Water Pumps & Tanks

| | | | | |
|---|---|---|---|---|
| 600 KW | 1 Boiler + 1 Reserve | $ 372,000 | + [illegible] | = $ 342,000 |
| 1250 KW | 1 Boiler + 1 Reserve | 458,000 | 23000 | = $ 483000 |
| 1750 KW | 2 " + 2 Reserve | 612 000 | 40,000 | = $ 652000 |
| 2500 KW | 2 " + 2 " | 705,000 | 40,000 | = $ 745,000 |

Includes, Boiler, Gas, Fans, Soot Arrestor, 40 ft stack all controls Storage Tank for 60 Hrs Delivery & controls

CIRCULATE TO:

ACRES



# Memo Re Telephone Call

JOB No. P

DATE Sept 12/84

FILE No.

FROM (Originator) Peter Ackroyd

Company

TO M. Mills (taken by P. Gill)

Company

SUBJECT

- Duplex pump set c/w tank ; each with 30 hp motor
  $14,680 ( not incl. taxes)

- assumes 180°F feed water
- 600 ft head ; each pump rated at 86 usgpm
- tank capacity 504 U.S. gal.

- doesn't include starters ; if need these, add $300.

CIRCULATE TO:

CONDENSER TUBE

ACRES SNF

WAJAX MTL

JULY 27/84

MSG 485

ATT: S. RICHTER

1. RE UR P7150.00, COPPUS-MURRAY QUOTE 6226, WE ADVISE AS FOLLOWS:-

| RATING | BUDGET PRICE US | CAN FACTORY |
|---|---|---|
| 50 KW | = 25,000 x1.6 | 40000 |
| 100 KW | = 29,000 " | 46400 |
| 200 KW | = 39,000 " | 62400 |
| 300 KW | = 42,000 " | 67200 |
| 400 KW | = 47,000 " | 75200 |
| 600 KW | = 55,000 " | 88,000 |
| 1250 KW | = 72,000 " | 115200 |
| 1750 KW | = 89,000 " | 142400 |
| 2500 KW | = 108,000 " | 172,800 |

PRICE INCLUDES SURFACE CONDENSER FOR 95 F WATER IN 115 F MAX OUT 0.0005 FOULING FACTOR, AIR REMOVAL PACKAGE, LIQUID LEVEL CONTROL, DUAL PUMPS AND RELIEF VALVE.

2. TERMS AND CONDITIONS ARE PER AFFILIATED LETTER JULY 13/84

TX

TIMMINS TRANE MURRAY / AFFILIATED ENGINEERING

WAJAX MTL

ACRES SNF

IN RESPONSE TO YOUR TX ABOVE WE OFFER FOLLOWING BUDGETARY PRICING

WOODCHIP BURNING P.S. STUDY



(A) 600 KW

ONE - TURBO ALTERNATOR SET COMPRISING TURBINE FRAME 22A, 15 INCH DIA 8 STAGES GOVERNOR, GAUGE BOARD, INTEGRAL CONTROL AND LUBE. OIL SYSTEM, GEARBOX, INTEGRAL CONDENSER, ALTERNATOR (440V - 3 PH - 60 HZ ASSUMED) AND A.V.R.

BUDGET PRICE DLLRS 456,000 FOB NEAREST RAIL HEAD

WITH STEAM AT STOP VALVE CONDITIONS OF 230 PSIG 0.98 DRY THE TURBINE REQUIRED 10,400 LB/HR OF STEAM TO PRODUCE 600 KW AT THE ALTERNATOR TERMINALS WHEN EXHAUSTING TO CONDENSER AT 28 INCHES HG VACUUM. 1500 I.G.P.M. OF COOLING WATER REQUIRED AT ASSUMED INLET TEMP OF 27 DEG C (80.6 DEG F).

(B) 1250 KW

ONE - TURBO-ALTERNATOR SET COMPRISING TURBINE FRAME 7A-18 INCH DIA. 7 STAGES OTHERWISE AS ABOVE.

BUDGET PRICES DLLRS 616,700 FOB NEAREST RAIL HEAD

STEAM FLOW 21,200 LB/HR EXHAUST 27.25 INCHES HG
COOLING WATER FLOW 1800 I.G.P.M. AT 27 DEG C.

(C) 1750 KW

ONE - TURBO-ALTERNATOR SET COMPRISING FRAME 71 TURBINE 22 INCH DIA 8 STAGES OTHERWISE AS ABOVE.

BUDGET PRICE DLLRS 648,820 FOB NEAREST RAIL HEAD.

STEAM FLOW 28,450 LB/HR EXHAUST 27.4 INCHES HG
COOLING WATER FLOW 2580 I.G.P.M.

(D) 2500 KW

ONE - TURBO-ALTERNATOR SET COMPRISING FRAME 7A TURBINE 22 INCHES DIA 8 STAGES OTHERWISE AS ABOVE

BUDGET PRICE DLLRS 676,700 FOB NEAREST RAIL HEAD

STEAM FLOW 41550 LB/HR EXHAUST 26.25 INCHES HG
COOLING WATER FLOW 2580 I.G.P.M.

THE ABOVE PRICES ARE FIXED FOR STD. DELIVERY OF 10 MONTHS FROM ORDER FOB UK PORT AND VALID FOR 90 DAYS.

OFFER MADE SUBJECT TO TERMS OF PAYMENT INCLUDING PROGRESS PAYMENTS DURING COURSE OF MANUFACTURE.

TRUST THIS MEETS YOUR IMMEDIATE NEEDS.

RGDS
A.J. WINFIELD
GEC CANADA LTD

McRAE ENGINEERING EQUIPMENT LIMITED
ENGINEERS

422-3738
TELEX: 06-219663

UNIT 31
2 THORNCLIFFE PARK DRIVE

TORONTO, ONT.
M4H 1H2

RECEIVED
AUG 27 19..
Acres Consulting Services Ltd.

August 22, 1984.

Acres Consulting Services
44 Torbay Road,
St. Johns, Newfoundland.
A1A 2G4

Attention: Maurice Mills,

Gentlemen

RE: TURBO GENERATORS

Further to your July 12/84 telex to turbodyne - McGraw edison Mr. Tucker we are pleased to offer the following budget pricing and efficiency for your reference.

McRae Engineering is the authorized factory representation for turbodyne in eastern Canada. We suggest for any future information you should contact us as we should be able to respond faster than the factory for budget estimates.

The packages offered include the steam turbine, reduction gear and generator all mounted together on a baseplate with lubrication system and turbine governor control system. They do not include condenser or switch gear.

A. Croque

| | |
|---|---|
| Steam Cond. | 230 psig sat. 4 in. Hg. |
| Turbine Model | 501T |
| Speed | 5500/1800 |
| Power | 100 KW |
| Steam Rate | 33.3 #/KW HR |
| Part Load | 90 KW 80 70 60 50 40 |
| Stm Rt. | 34.0 34.8 35.8 35.2 36.6 39.3 |
| | 30 KW 20 |
| | 41.7 49.0 |
| Budget Price | $43,000 |
| Est Size | 14 Ft. X 4 X 4 Ft. |
| Est Wt. | 8000 Lb. |

B. Main Brook

| | |
|---|---|
| Steam Cond. | same |
| Turbine model | 701T |

| | | |
|---|---|---|
| | Speed | 5200/1800 |
| | Power | 200 KW |
| | Stm Rate | 27.4 #/KW HR |
| | Part Load | 180KW 160 140 120 100 80 60 40 |
| | | 27.4 27.5 28.3 29.2 29.9 30.7 33.0 35.3 |
| Budget Price | | $58,400.00 |
| Est. Size | | 14 Ft. X 4 X 4 Ft. |
| Est. Wt. | | 9000 Lb. |

B-1 Main Brook

| | | |
|---|---|---|
| | Turbine model | 701 LPW |
| | Speed | 5200/1800 |
| | Power | 400 KW |
| | Stm Rate | 26.6 #/KW HR |
| | Part Load | 360KW 320 280 240 200 160 120 80 |
| | | 26.6 27.2 27.3 28.2 29.4 31.3 34.5 40.7 |
| Budget Price | | $89,900.00 |
| Est. Size | | 16 X 4 X 4 Ft. |
| Est. Wt. | | 12000 Lb. |

C. Roddickton

| | | |
|---|---|---|
| | Turbine Model | 701 LPW |
| | Speed | 5200/1800 |
| | Power | 600 KW |
| | Steam Rate | 26.6 #/KW HR |
| | Part Load | 540KW 480 420 360 300 240 180 120 |
| | | 26.6 26.7 27.2 27.8 28.7 30.2 32.3 37.5 |
| Budget Price | | $91,200.00 |
| Est. Size | | 16 X 4 X 4 Ft. |
| Est. Wt. | | 14000 Lbs. |

| | | |
|---|---|---|
| C-1 | Turbine Model | S-4 Multi |
| | Speed | 5500/1800 |
| | Power | 1000 KW |
| | Steam Rate | 20.1 #/KW HR |
| | Part Load | 900KW 800 700 600 500 400 300 200 |
| | | 20.2 20.4 20.7 21.1 21.7 22.7 24.5 28.3 |
| Budget Price | | $172,600.00 |
| Est. Size | | 20 X 5 X 5 Ft. |
| Est. Wt. | | 25000 Lbs. |

| | | |
|---|---|---|
| C-2 | Turbine Model | S-8 Multi |
| | Speed | 4500/1800 |
| | Power | 1500 KW |
| | Steam Rate | 19.0 #/KW HR |
| | Part Load | 1350KW 1200 1050 900 750 600 450 300 |
| | | 19.0 19.1 19.3 19.7 20.2 21.1 22.7 26.1 |
| Budget Price | | $243,000.00 |
| Est. Size | | 24 X 6 X 6 Ft. |
| Est. Wt. | | 40,000 Lbs. |

| | | |
|---|---|---|
| C-3 | Turbine Model | T-8 Multi |
| | Speed | 4500/1800 |
| | Power | 2000 KW |
| | Steam Rate | 17.35 #/KW HR |
| | Part Load | 1800KW 1600 1400 1200 1000 800 600 400 |
| | | 17.45 17.75 18.0 18.5 18.8 19.1 22.1 26.1 |

| | |
|---|---|
| Budget Price | $336,000.00 |
| Est. Size | 28 X 6 X 6 Ft. |
| Est. Wt. | 50,000 Lbs. |

Prices show are net, in bond U.S. funds, taxes extra.
The duty rate for this equipment is 15%.

We would recommend a steam separator ahead of the turbines to reduIe moisture (see attached)

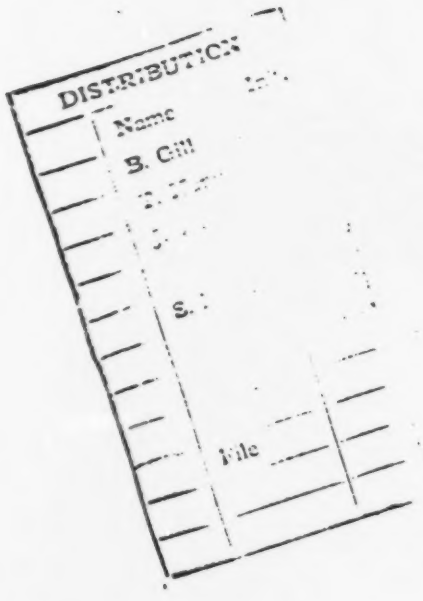
Our factory is in Wellsville New York. A serviceman costs $580.00/day U.S. funds.

Turbodyne do not recommend going below about 20% load on isolated generators as the possibility for frequency variations becomes very real. On systems in a grid you can go down to 0 load without any problems.

Yours truly,

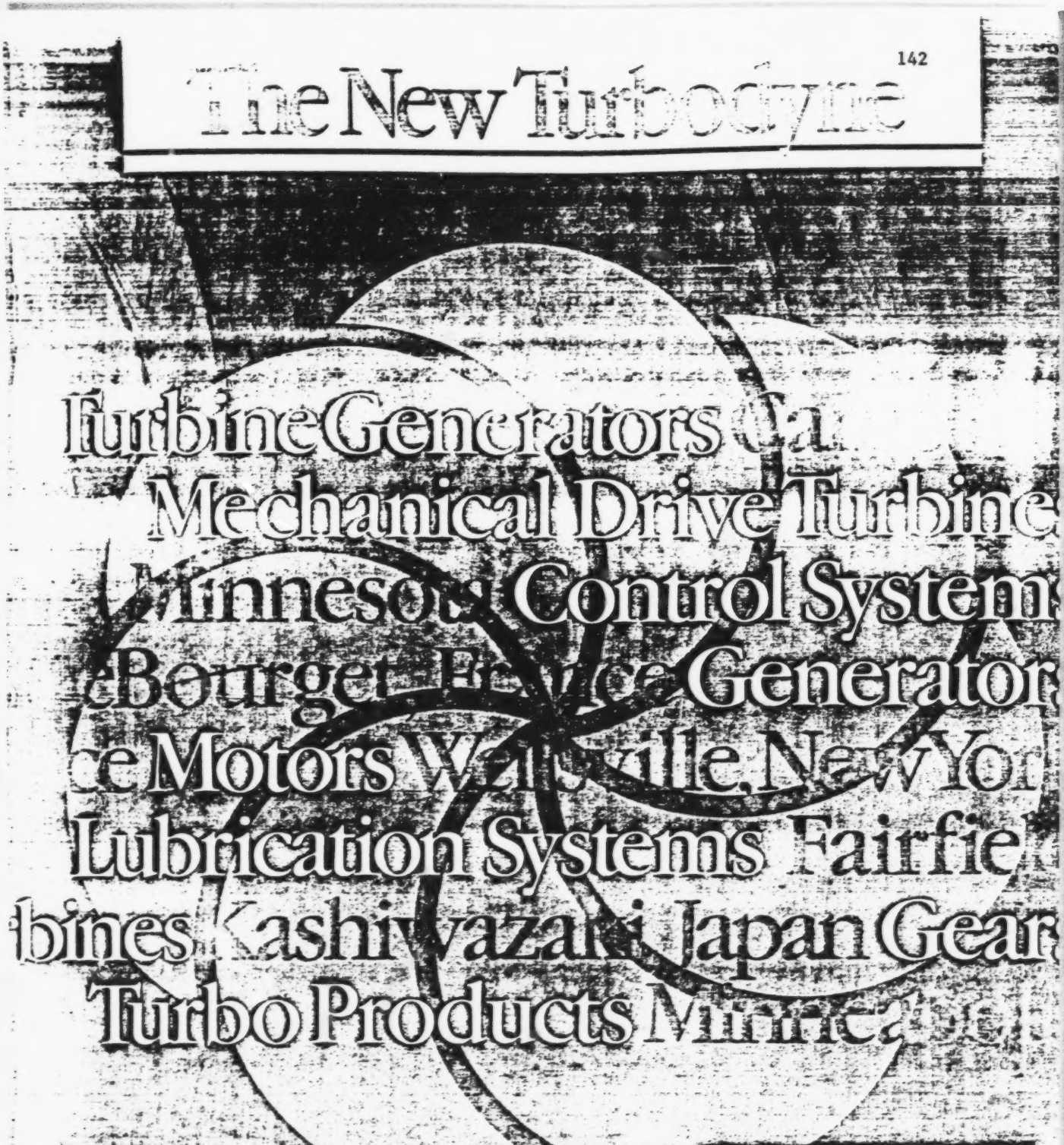
D. DUTHIE
McRAE ENGINEERING EQUIP. LTD.,

sj/DD



# Appendix C
# Manufacturers Information

# The New Turbostyle




McRAE ENGINEERING EQUIPMENT LIMITED
2 Thorncliffe Park Drive, Unit 31
Toronto, Ontario M4H 1H2
Telephone 422-3735 Telex 06-219663
Sarnia Telephone 1-519-337-7671

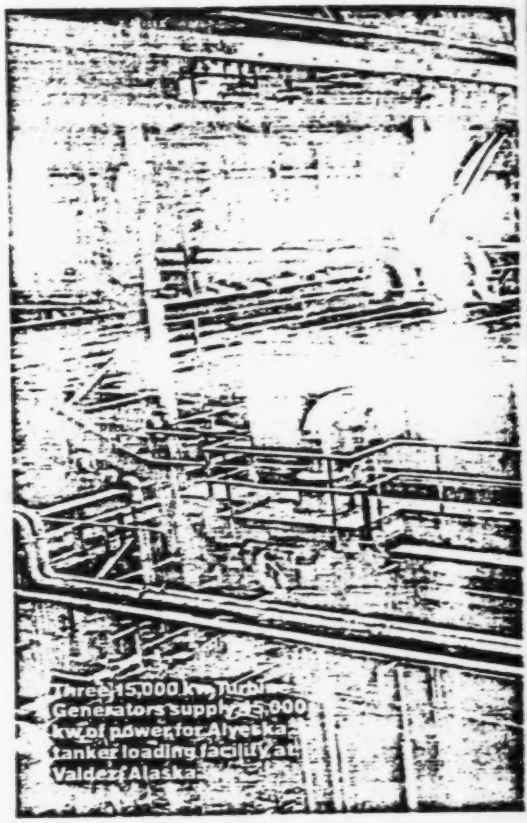
Turbodyne Steam Turbine Generators provide the finest quality and the highest efficiencies available today. More than 65 years of design and manufacturing experience, and hundreds of Turbine Generator installations, worldwide, are powerful proof of that.

### The Systems Approach to Power Generation

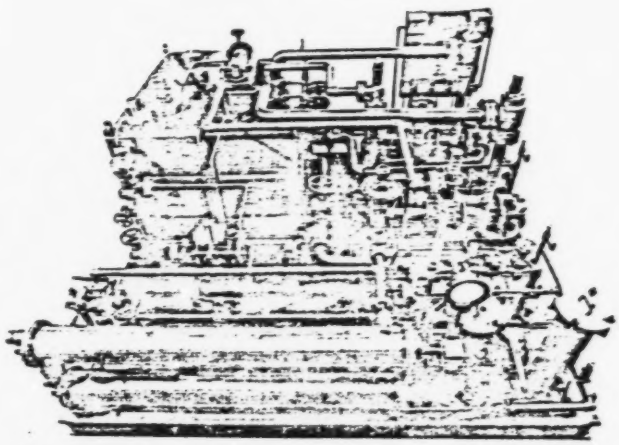
We evaluate your Turbine Generator needs as a completely integrated system, and we can design and manufacture a power package that meets your exact system configuration, operating conditions and output requirements. Turbine, generator, gearing as needed, lubrication system, governor and extraction controls, switchgear and safety devices are all supplied and serviced by one reliable source.

What's more, our line of Turbine Generators provides the most complete coverage to 60,000 kw.

As your single source of products and services, we maximize your return on investment through low initial cost, efficient operation and low maintenance.



Three 15,000 kw Turbine Generators supply 45,000 kw of power for Alyeska tanker loading facility at Valdez, Alaska.



Turbodyne Oil Lubrication Systems are designed to enhance overall dependability.

| Turbines |
| --- |
| Backpressure |
| Condensing |
| Extraction/noncondensing |
| Extraction/condensing |
| Low pressure condensing |
| Induction/condensing |
| Extraction/induction |
| **Generators** |
| Cylindrical Rotor Synchronous Generators |
| Salient Pole Synchronous Generators |
| Induction Generators |

Three 30,000 kw Turbine Generators for a Refuse-Derived Fuel utility power plant.



Controls for paralleling, emergency power, peak shaving and other functions are carefully specified for maximum performance.

| Turbine Generators | Configuration | Capabilities |
|---|---|---|
| **Standard** | Single valve/geared | 50-5000 kw |
| **Engineered** | Single valve/geared | 50-5000 kw |
| | Multivalve/geared | To 12,000 kw |
| | Multivalve/direct connected | To 60,000 kw |

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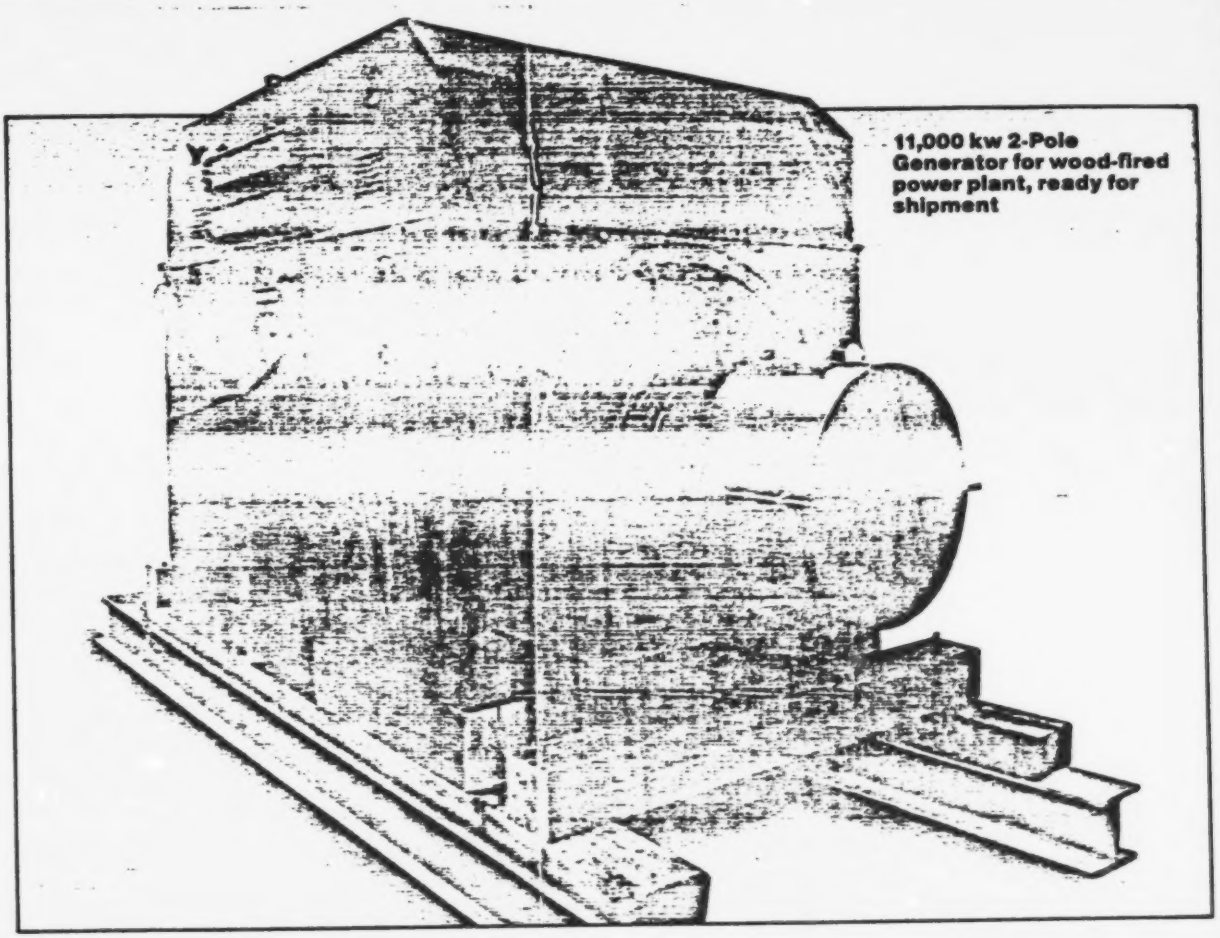


**11,000 kw 2-Pole Generator for wood-fired power plant, ready for shipment**

## Generators

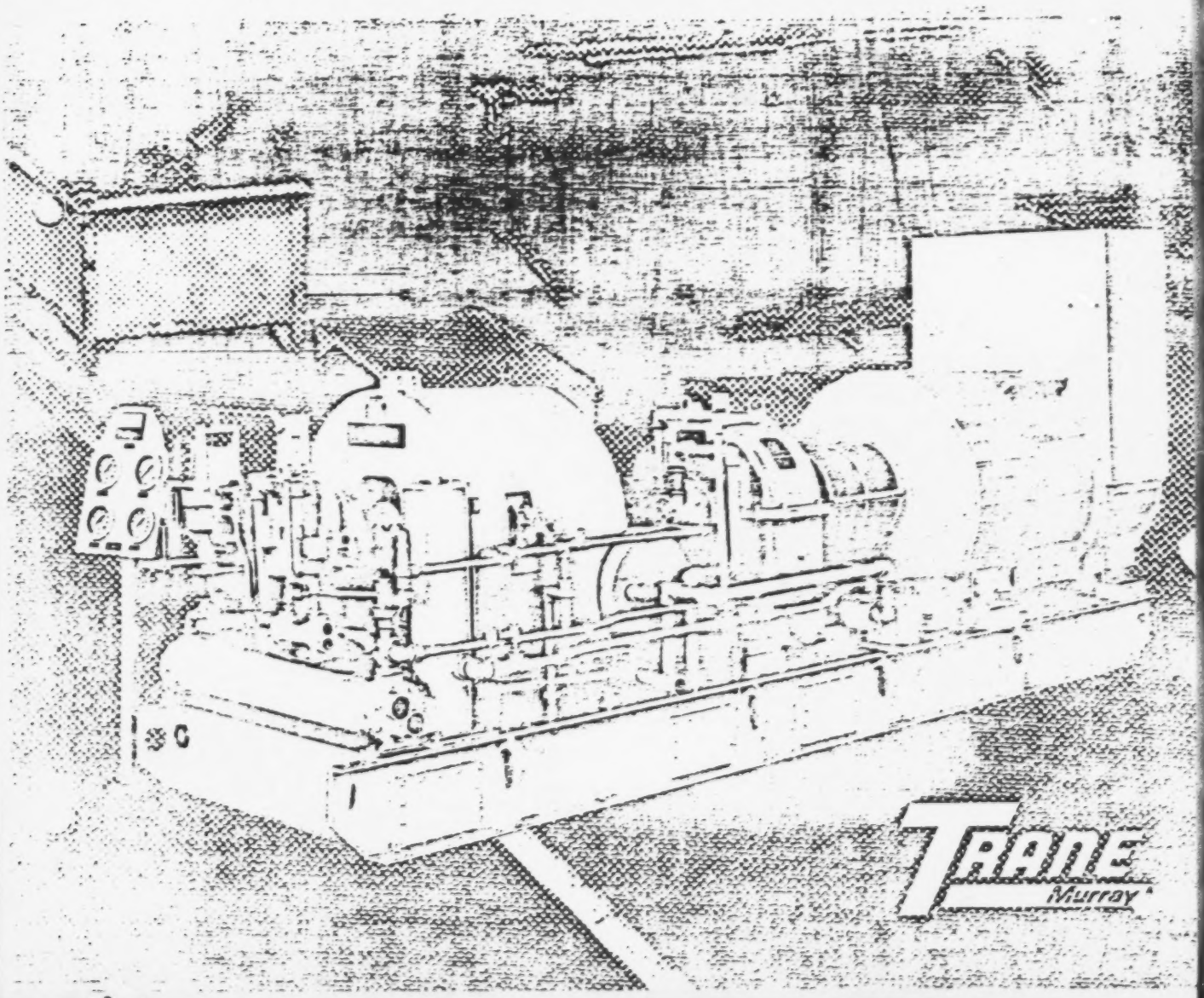
| rpm | Rating (kw) | Equipment | Options |
|---|---|---|---|
| Below 450 | 1500-40,000 | Reciprocating Engines<br>Hydroturbines | 2300-14,000 Volts<br>Horizontal and Vertical<br>Open or Enclosed<br>Brushless Excitation<br>Voltage Regulator<br>Driver<br>Enclosures:<br>Open Dripproof<br>Weather Protected I<br>Weather Protected II<br>TEWAC<br>TEFV |
| 450-1200 | 1500-10,000 | Reciprocating Engines<br>Hydroturbines | |
| 1200-1800 | 1500-20,000 | Steam Turbines<br>Gas Turbines | |
| 3600 | 5000-100,000 | Steam Turbines<br>Gas Turbines | |

**2-Pole Generators**
We've installed more than 18 million kilowatts in 2-Pole Generator power. Our 3600 rpm generators provide from 5000 to 100,000 kw, used with gas and steam turbine drives.

**Salient Pole Generators**
EM Salient Pole Generators provide 1500 to 20,000 kw at 1800 rpm and slower speeds. Hydrogenerators from 1500 to 40,000 kw are also available.

# Trane Murray Turbogenerator Sets

Efficient, in-plant electrical generation with steam.



TRANE
Murray

# Turbogenerators



# Packaged Turbogenerator Sets can cut energy costs through cogeneration or peak shaving.

If steam is available, Trane can supply the equipment and know-how needed to help generate your own electricity and cut energy costs. Whether choosing to save dollars through cogeneration or peak shaving, the return on investment is substantial.

Savings and cycle efficiency can both be optimized by using the steam produced for simultaneous use in electrical generation, process heating or cooling requirements. Not only are electrical energy charges reduced, but chances are a reduction in demand charges can be made because electrical peak loading is reduced.

In addition, the electrical power supply is protected against power outages, brownouts, or reduced voltage conditions. Important protection needed in making sure plant operations continue efficiently despite outside power interruptions.

Besides the basic energy savings application of cogeneration, a Trane Murray turbogenerator set allows the use of excess low pressure steam as an energy source. And steam as low in pressure as 1 psig can be put to use generating power with a Trane Murray unit.

## Other Working Fluids

Besides steam, a Trane Murray turbogenerator can also efficiently make use of other pressurized energy sources. Natural gas, air, nitrogen, and methane have all been successfully used in place of steam expansion to generate power with Trane Murray equipment.

## Total Package

Trane Murray turbogenerator sets are computer designed to fit your steam conditions and electrical application needs. Packages may include either a multi-stage or single-stage steam turbine, a speed reduction gear, generator, lubrication system and controls.

All sets are packaged, coupled, and factory tested to lower installation time and reduce on-site costs.

## Turbine

To provide optimum efficiencies for steam conditions and applications, Trane Murray turbines can be selected from a broad line of single and multi-stage models.

## Reduction Gear

To make certain each turbine operates at its most efficient speed, Trane Murray turbogenerator sets also include a speed reduction gear in the power train.

## Generator

Generators may be provided with open drip-proof construction up to 5,000 kw or totally enclosed water-to-air cooled, 50-10,000 kw design. Again, generator type and electrical characteristics are selected to meet the special needs of Trane Murray customers.

©THE TRANE COMPANY 1980

TRANE Murray

## Turbogenerator Capabilities

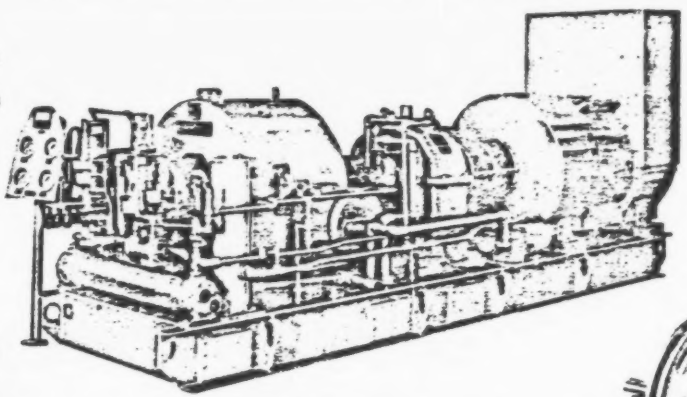
148

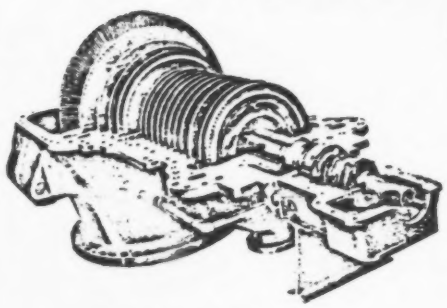
| Capabilities | Maximum | Minimum |
|---|---|---|
| Output (kw) | 10,000 | 50 |
| Inlet Steam Pressure (psig) | 900 | 1 |
| Steam Inlet Temperature (F) | 850 | 216 |
| Exhaust Steam Pressure (psig) | 300 | Vac. |

## Dimensions

| KW | Length (ft) | Width (ft) | Height (ft) | Weight (lbs) |
|---|---|---|---|---|
| 50 | 14 | 6 | 5 | 15,500 |
| 100 | 14 | 6 | 5 | 16,000 |
| 200 | 14 | 6 | 5 | 16,500 |
| 300 | 14 | 6 | 5 | 17,000 |
| 400 | 15 | 6 | 5 | 19,000 |
| 500 | 15 | 6 | 5 | 20,000 |
| 600 | 16 | 7 | 5 | 21,000 |
| 700 | 16 | 7 | 5 | 22,000 |
| 800 | 17 | 8 | 5 | 24,000 |
| 900 | 18 | 8 | 5 | 25,000 |
| 1,000 | 19 | 8 | 5 | 26,000 |
| 1,250 | 19 | 8 | 5 | 30,000 |
| 1,500 | 20 | 8 | 5 | 33,000 |
| 1,750 | 21 | 8 | 5 | 36,000 |
| 2,000 | 22 | 8 | 5 | 39,000 |
| 2,250 | 23 | 9 | 7 | 42,000 |
| 2,500 | 23 | 10 | 7 | 45,000 |
| 3,000 | 24 | 11 | 7 | 52,000 |
| 4,000 | 25 | 12 | 7 | 65,000 |
| 4,500 | 26 | 12 | 7 | 71,000 |
| 5,000 | 27 | 12 | 7 | 77,000 |
| 5,500 | 27 | 12 | 7 | 84,000 |
| 6,000 | 28 | 13 | 7 | 90,000 |
| 7,000 | 29 | 13 | 7 | 103,000 |
| 8,000 | 30 | 13 | 7 | 115,000 |
| 9,000 | 31 | 13 | 7 | 125,000 |
| 10,000 | 32 | 13 | 7 | 135,000 |

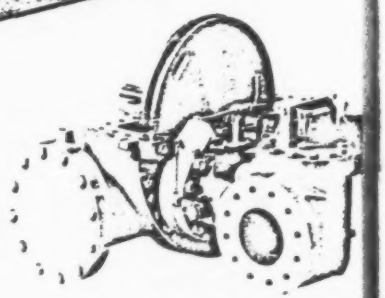
**Turbogenerator**
Co-generation Packages
50 to 10,000 kw
Turbine Gear Generators
Lube Systems
Complete Controls





**Multiple Stage Turbines**
Up to 15 Stages
API 611 and 612
500 to 15,000 bhp
Up to 900 psig Inlet
Up to 850 F Inlet
Up to 300 psig Exhaust

**Single Stage Turbines**
API 611
200 to 2,500 bhp
Up to 700 psig Inlet
Up to 750 F Inlet
Up to 150 psig Exhaust



TRANE

PROCESS DIVISION
THE TRANE COMPANY, LA CROSSE, WISCONSIN 54601

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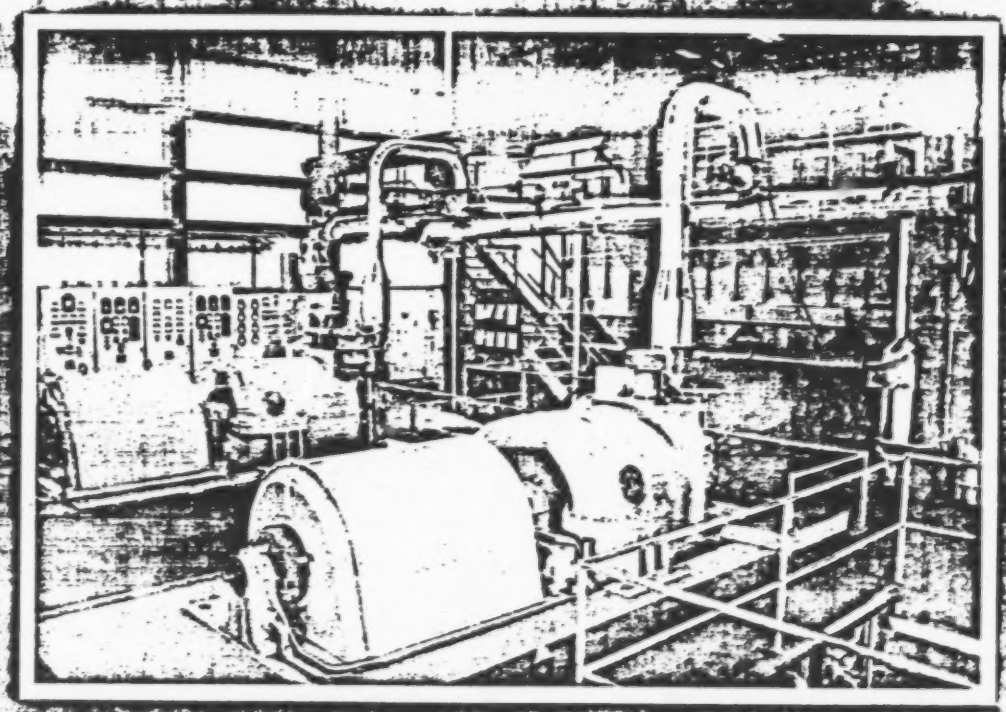
# WELLONS



## ELECTRICAL GENERATION SYSTEMS

**Are you interested in making electricity for sale or for your own in-plant use, cutting operating costs and increasing profits?**

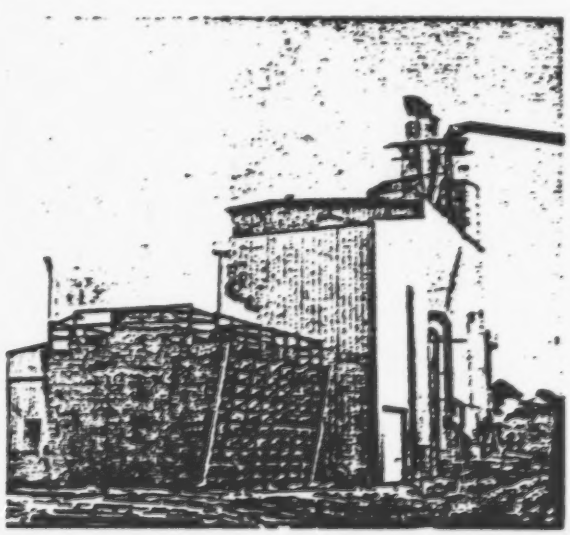
**Do you have steam requirements for a process, or is steam now being used in your plant without cogenerating?**

**Are you confronted with increasingly expensive natural gas or fuel oil costs?**

**Do you have a disposal problem with a solid fuel by-product or industrial waste?**

## CONSIDER THE FOLLOWING:

Wellons has been in the steam generating systems business for over twenty years, engineering and manufacturing a full line of proprietary equipment burning solid organic fuels for industrial and agricultural applications. Headquartered in Sherwood, Oregon, near Portland, we have a sales and service office in Atlanta, Georgia, and employ nearly 100 people, exclusive of field installation personnel. There are Wellons installations in 31 states and Canada. We have over 130 successful steam generating systems in service, with involvement in 13 cogeneration facilities to date.



Cogeneration installation fueled by hogged wood waste with Wellons boiler system. Fuel storage is in the background with a cooling tower in the foreground. The plant cogenerates electricity and process steam from the solid organic mill by-product.

CO-GENERATION - Wellons offers complete engineering and management for your total project, beginning with feasibility studies, support with PURPA and FERC regulations, regulatory filings, applications engineering and environmental and economic analyses. We can handle the total cogeneration project from the fuel conveying and storage system, boiler and combustion system, electrical generation system, building enclosures, all mechanical and electrical controls and instrumentation to the final electrical switch yard and process steam-system.

BIOMASS FUELS - Wellons has experience burning various types of fuels, from the more traditional hogged wood waste fuel, high in moisture content, to dry sunflower seed hulls, corn cobs, almond and grape prunings, nut shells, olive and peach pits in blended combinations. We also burn combinations of coal, shredded rubber tires, plain and waxed corrugated cardboard and various other industrial residues.

MANUFACTURING - Well known for complete manufacturing capability in fuel storage, steam generating and lumber drying systems, we also build sophisticated pneumatic and electrical control panels required to operate these systems, as well as turbine control, generator and line supervisory panels for electrical generation - tailored for the specific application.

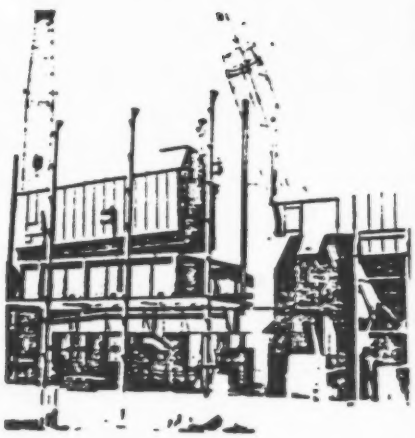
CONSTRUCTION - Wellons is a licensed contractor handling projects including site preparation, piling, equipment foundations, building erection and all mechanical and electrical equipment installation - including checkout and startup service. Projects are planned and scheduled by use of modern CPM techniques, assuring on-time completion.

TRAINING - Wellons has always provided operator orientation, but as our systems have developed and become more complex, we have instituted formal classroom training programs in operation, maintenance and basic engineering theory. Audio and video tape presentations will soon be available for on-going use by owners of Wellons systems.

- ENGINEERING
- MANUFACTURING
- MANAGEMENT
- PROCUREMENT
- CONSTRUCTION
- EQUIPMENT INSTALLATION
- TRAINING
- STARTUP & TESTING
- FIELD MAINTENANCE SERVICE
- SHOP REPAIR & OVERHAUL

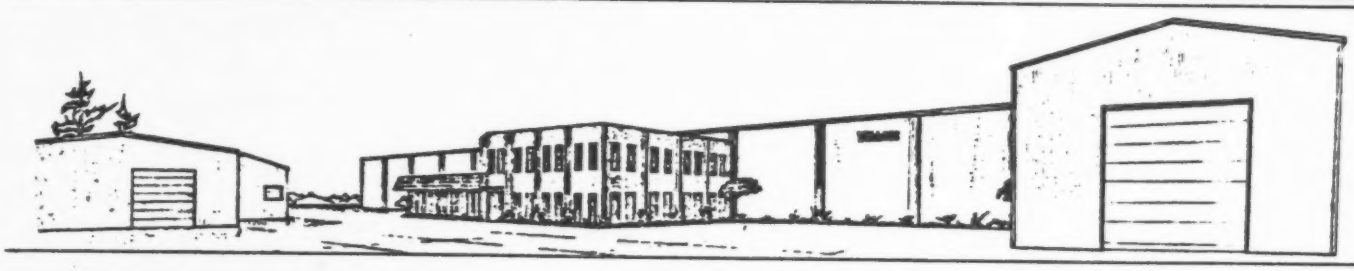
Design and engineering work areas. Specialists are at work on the various layouts and details of our multifaceted systems. Drawings are prepared for manufacturing and construction, as well as technical publications used in operation and training manuals.

Nearly 80,000 sq. ft. of covered shop space is available for manufacturing and reconditioning work. Work areas are segregated into basic stations such as fabrication, shaping, forming, painting, precision work and electrical.



Construction of what we engineer and manufacture rounds out Wellons' full service capability. All tools, materials, supervision and labor are provided to build your plant. Shown is a heavy lift of the boiler during erection of the plant.

U.S. Patents: 3027881 3215290 3330259 3339759 4098008 4233914 4266901
Canadian Patents: 1138193 1138426



WELLONS

WELLONS, INC. (503) 625-6131
P.O. BOX 381
SHERWOOD, OREGON 97140

ELECTRICAL GENERATION SYSTEMS
DIRECT FIRED SYSTEMS
BOILER PLANTS
STORAGE BINS
DRY KILNS

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BULLETIN 11000

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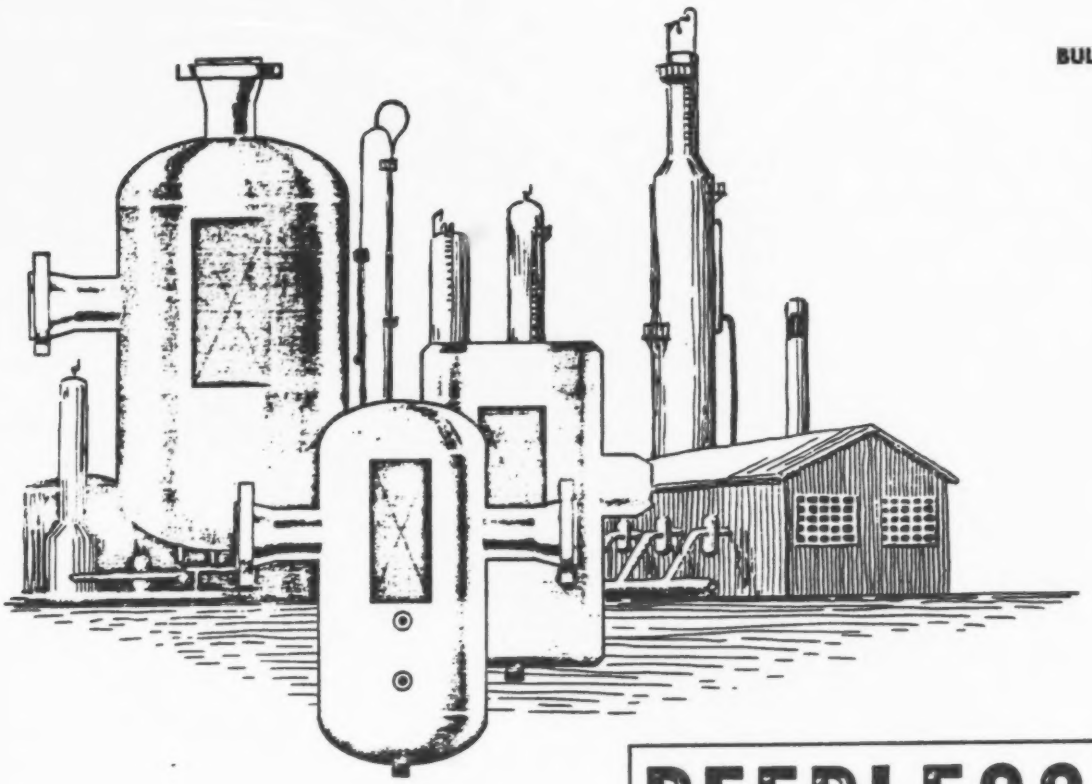

# PEERLESS

## VANE-TYPE

# LINE SEPARATORS

FOR RELIABLE, HIGH - EFFICIENCY SEPARATION OF ENTRAINED LIQUIDS FROM A GAS, SPECIFY PEERLESS — PROVED IN OVER 22,000 INSTALLATIONS THROUGHOUT THE WORLD.

PEERLESS MFG CO

DALLAS TEXAS

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Our Reference: 11-A-2

March 24, 1981.

Mr. J. Wright,
Acres Consulting Services Ltd.,
480 University Avenue,
Toronto, Ontario,
M5G 1X6.

Dear Mr. Wright,

In response to our telephone conversation I have pleasure in enclosing herewith a binder of publications describing the Brotherhood range of Turbines.

You will note that Brotherhood have devoted some time and design effort to packaging the Turbines and Condensers and also combining with Package Boiler Systems. A further subject they have devoted some time to is Waste Heat Recovery.

When you have had the opportunity of reviewing this information and if we can usefully review the matter further, I will be pleased to get together with you.

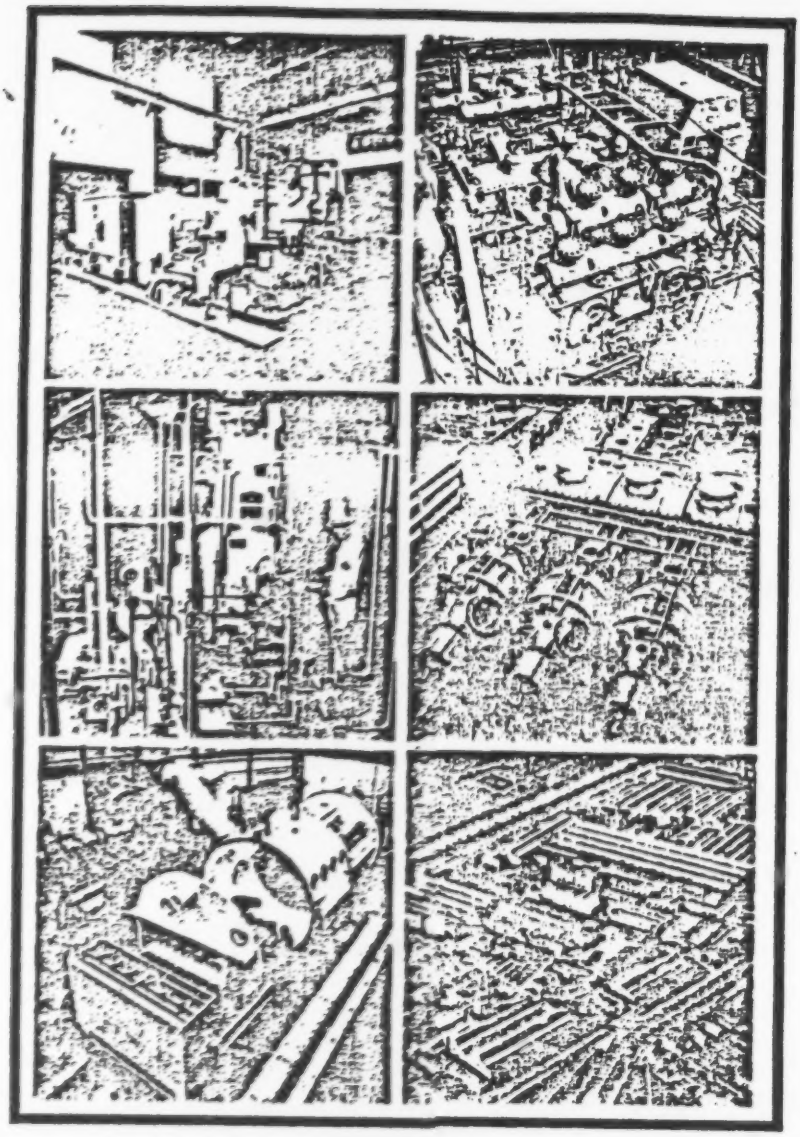
Yours very truly,

A. Huntington, P.Eng.
Vice President &
General Manager
Apparatus & Systems Division

AH/ej
Encl:

624-8300

Toronto, Ontario M5V 1N7 (416) 364-9281 Telex 065-24121



# BROTHERHOOD

Peter Brotherhood Limited
Lincoln Road Peterborough PE4 6AB England
Tel: 0733-71321 Telegrams: Brotherhood Peterborough Telex: 32154 Brhood G

Printed in England IAS Advertising 10/80

The commercial viability of WHR Systems for Industrial use changed dramatically in 1973 with the advent of the Oil Crisis, resulting in a steady growth of Brotherhood involvement. Waste heat is now being converted to usable energy in Chemical and petro-chemical refineries, fertilizer plants, pulp and paper mills, breweries, sugar mills and many more.

Turbo-generator packages have been installed by Brotherhood in a large variety of Industrial Plants throughout the world. With the recent signing of an agreement with an American Company a large potential market has been opened up in the New World, the most recent installation being for a mining Company in the Phillipines.

## HEAT SOURCES

These turbogenerators can use waste heat from a variety of sources including:

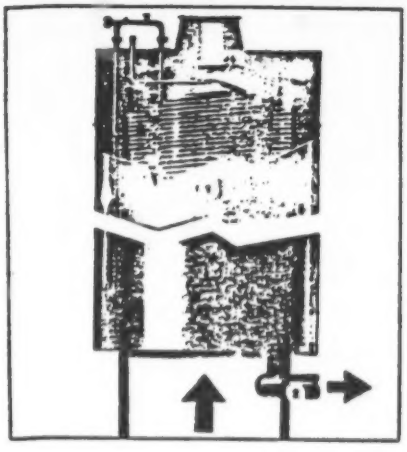
- diesel engine exhaust gases
- gas turbine exhaust gases
- refuse incineration and industrial manufacturing processes such as:
- fertilisers
- glass
- petrochemicals
- sucrochemicals
- cement
- electric smelting

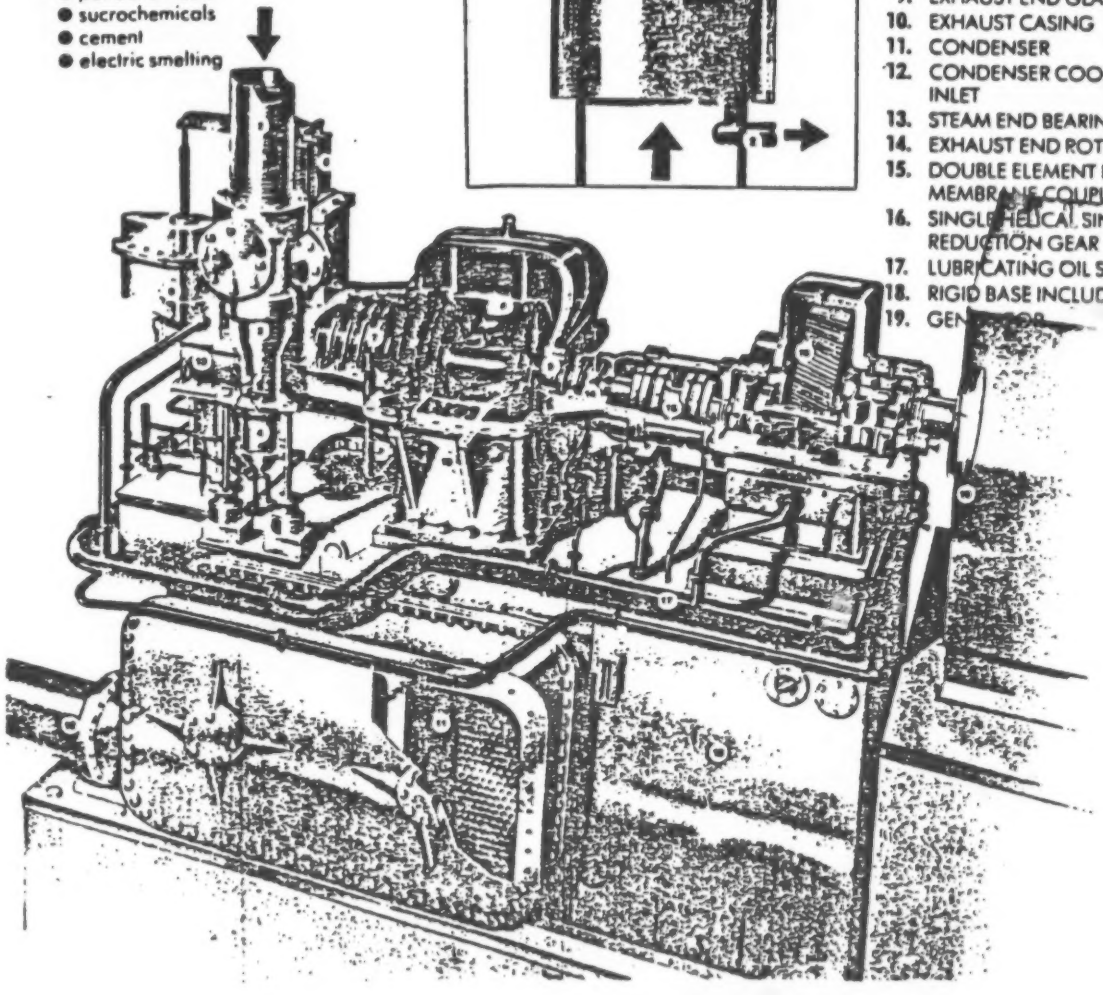
Heat Recovery schemes are now a viable industrial proposition, particularly in countries where government assistance is available.

Total energy schemes such as combined cycles, combined heat and power, and combined heat and power with district heating have a potential saving of up to 15% on fuel costs. The total energy concept is not new, but it is only in the last few years that its full potential has been appreciated with the conservation of limited energy supplies and cost saving by installing Brotherhood Waste Heat Recovery Systems.

A further viable concept yet to be fully utilised is a "grid balanced" system, whereby power is generated and the grid is used as a buffer or accumulator. Extra electricity is purchased when the demands are high, any surplus produced when the demands are low is fed into the grid. In view of the ever-growing world energy crisis it is in everyones' best interest to generate and preserve as much as possible of this WHR power.

Sometimes it may be beneficial to use power generating equipment utilizing a fluidised bed boiler supplying heat to a turbo-generator. The great attraction of this system is that it offers the economy of burning solid fuel usually high ash content coal and waste (garbage, acidtar etc.).





KEY

1. BOILER
2. MAIN STEAM PIPE
3. STEAM STOP VALVE
4. STOP VALVE TRIP CYLINDER
5. NOZZLE CONTROL VALVES
6. SERVO CONTROL MECHANISM
7. ROTOR BLADE PATH
8. DOUBLE FLOW EXHAUST
9. EXHAUST END GLAND
10. EXHAUST CASING
11. CONDENSER
12. CONDENSER COOLING WATER INLET
13. STEAM END BEARING PEDESTAL
14. EXHAUST END ROTOR BEARING
15. DOUBLE ELEMENT FLEXIBLE MEMBRANE COUPLING
16. SINGLE HELICAL SINGLE REDUCTION GEAR
17. LUBRICATING OIL SUPPLY
18. RIGID BASE INCLUDING OIL TANK
19. GENERATOR

**High speed single cylinder dou. low**

A range of turbine frames have been produced, such as that depicted in Fig 13, having double flow not only in the last stage but also, in some cases, in the penultimate stage. This construction has the advantage that the last row of turbine blades are greatly reduced in height, resulting in much higher speeds and smaller rotors with associated reduction of initial cost.

This arrangement is equally applicable to both pass-out or induction (mixed pressure) turbines and comes a long way towards meeting our ideal requirements of a two cylinder arrangement with HP and LP turbines giving maximum efficiency in Dual Pressure Cycles. It is certainly less complicated, cheaper and easy to operate, the difference in efficiency being marginal.

## 8. SOME PRACTICAL APPLICATIONS

Figure 13 – The sectional arrangement of a 3 plus 4 single stages plus 1 final double flow stage of a 5MW pass-out condensing turbine installed in a fertilizer factory.

Figure 14 – Section through a modern waste heat recovery geared turbine. This is a 6-stage 10,000/1, 800 R.P.M. unit integrated with a 440V, 3 Phase, 60Hz brushless C.A.C.W. alternator.

Figure 15 – A complete 1,100 kW packaged turbine, gear alternator assembly, completely tested at full load and ready for installation in a slow speed big bore diesel engined ship. This turbo-generator package needs only a single lift for transport to site, and then the necessary water, steam and electrical connections.

Figure 16 – Section of a geared pass-out back pressure turbine with 5 plus 2 single stages.

This machine was custom built. The complicated 3 valve pass-out gear was necessitated by the irregular balance between process steam and electrical power, while at the same time allowing for maximum efficiency and export of surplus electrical power to the Public Supply.

Figure 17 – Installation of a 4.2MW 10,000V, 3 Phase, 50Hz assembly in an internationally famous brewery. The turbine runs at 6,500 R.P.M. geared to the salient pole alternator at 1,500 R.P.M.

Figure 18 – An assembled and tested turbine gear, condenser water boxes have been removed for transport purposes.

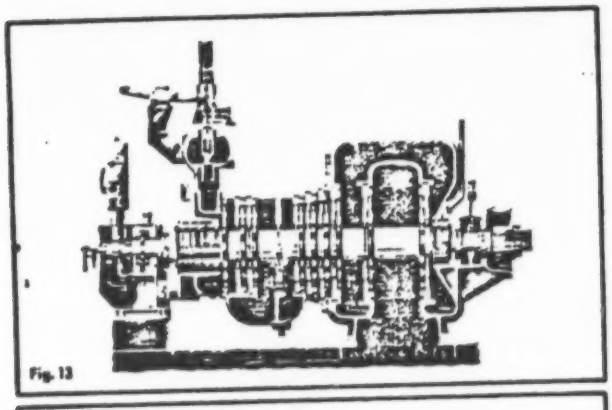


Fig. 13

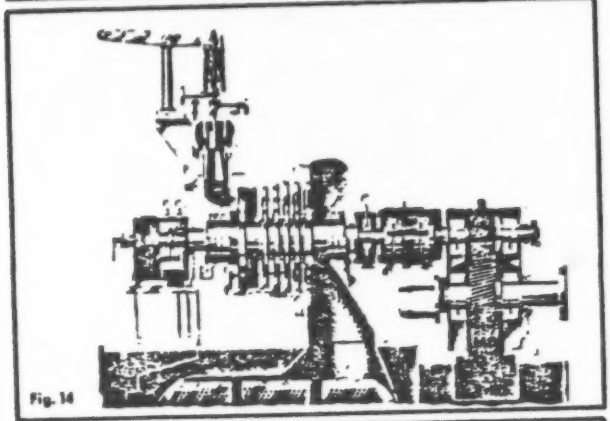
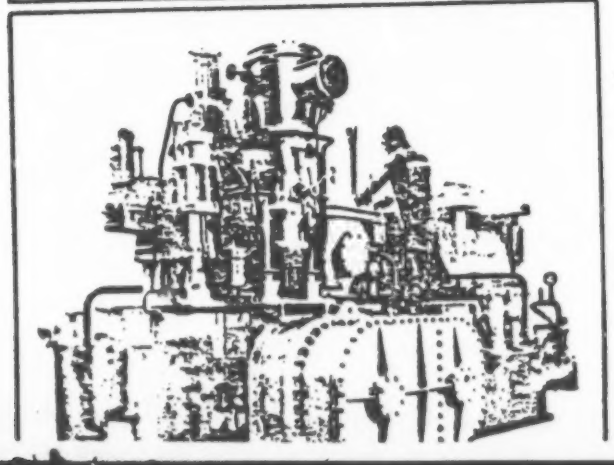


Fig. 14



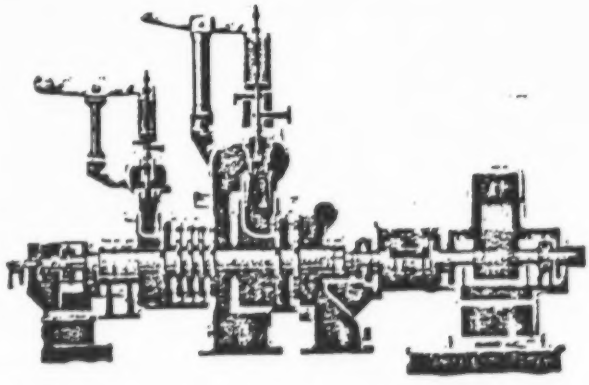


Fig. 16

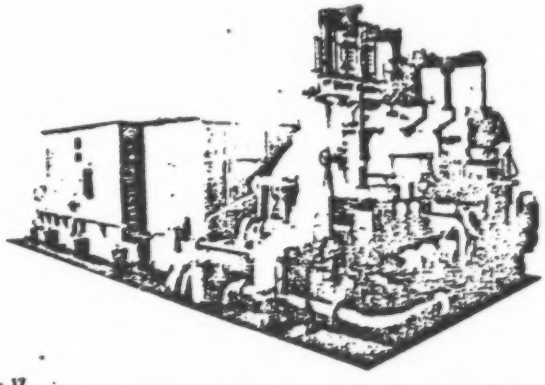
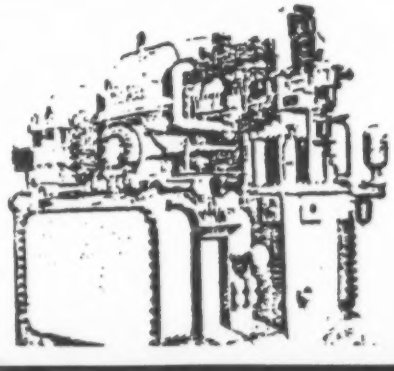


Fig. 17



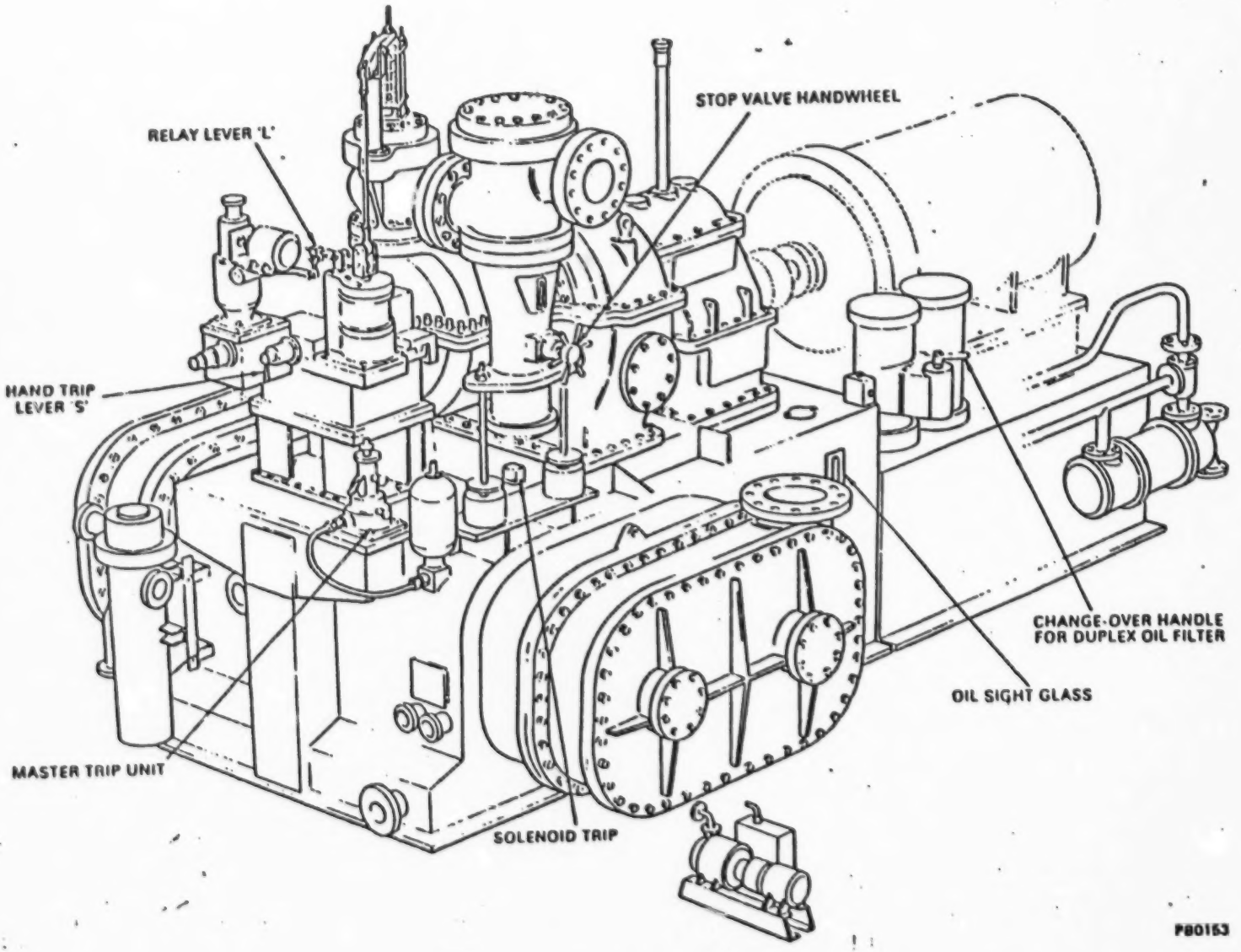



Fig.4. Turbine controls (R.H. view)

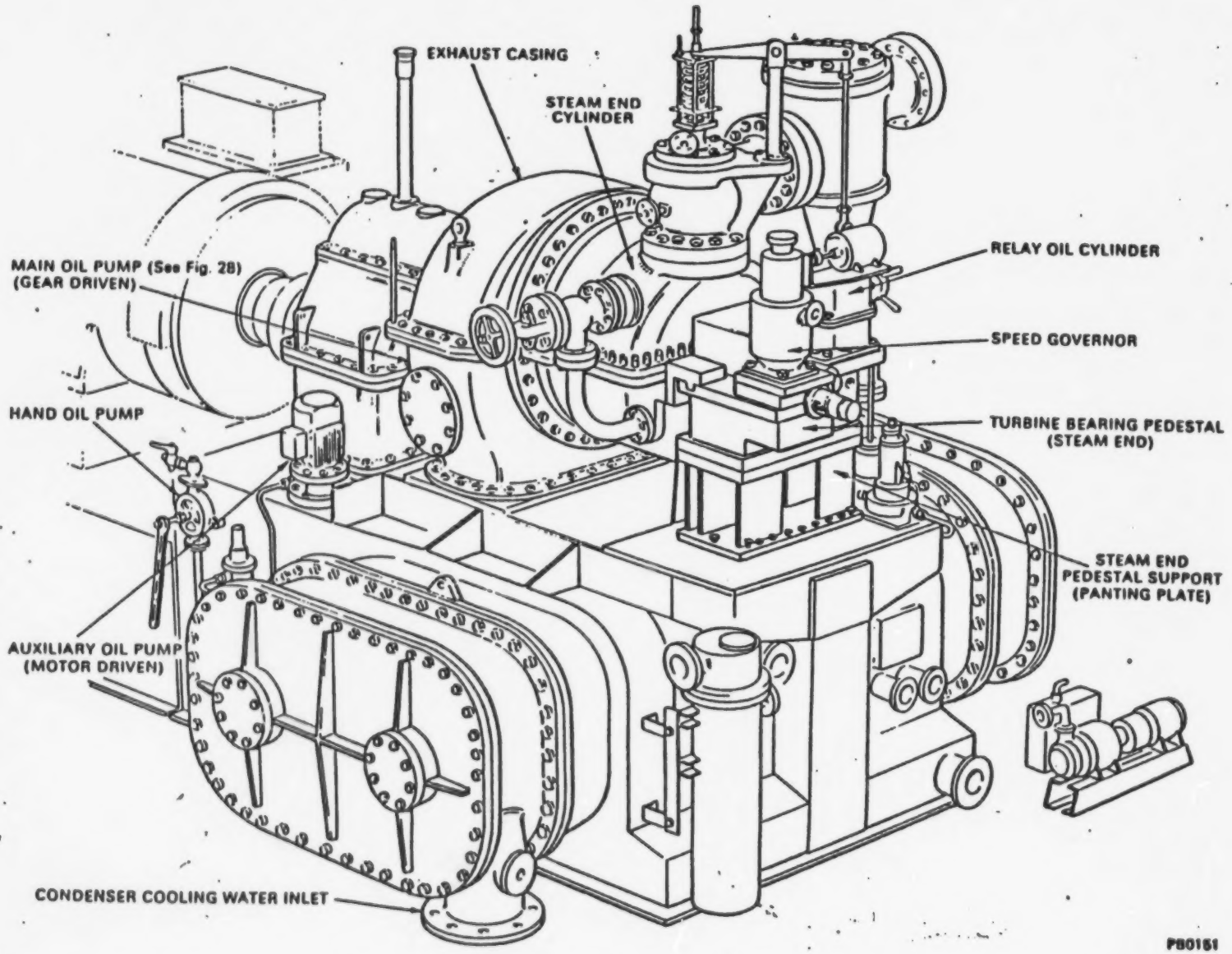
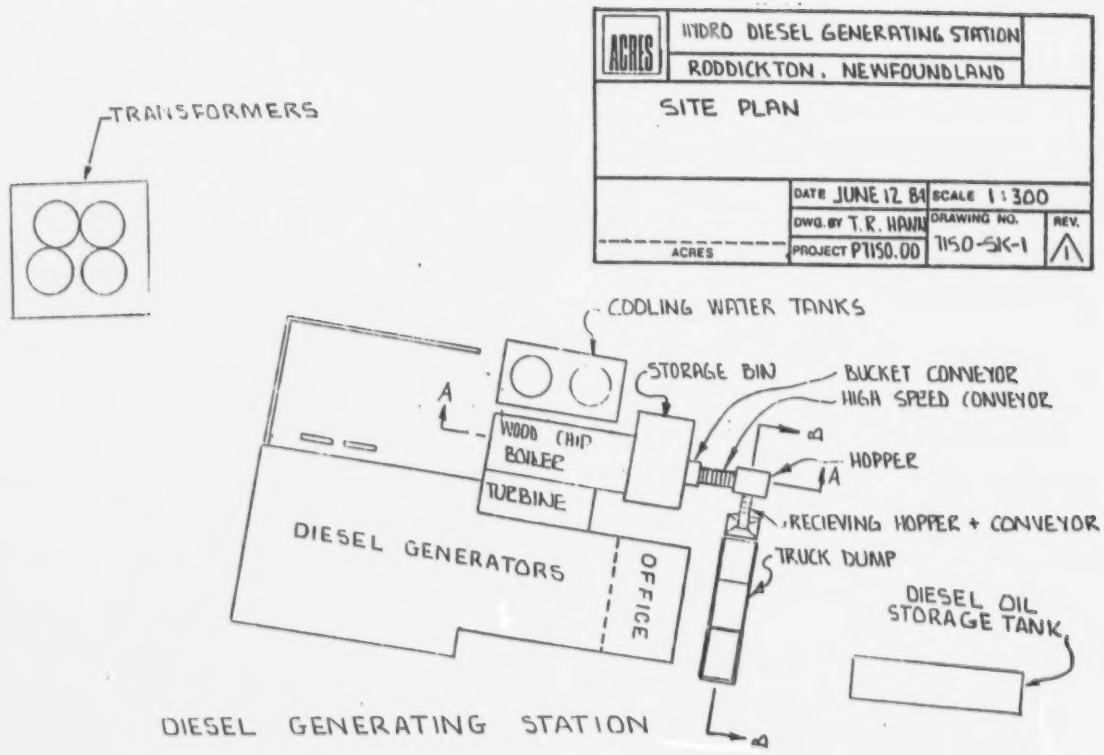



Fig.2. Principal components (L.H. view)

**Appendix D**
**Drawings**

7150-SK-1 - Site Plan
7150-SK-2 - Sections A-A, B-B



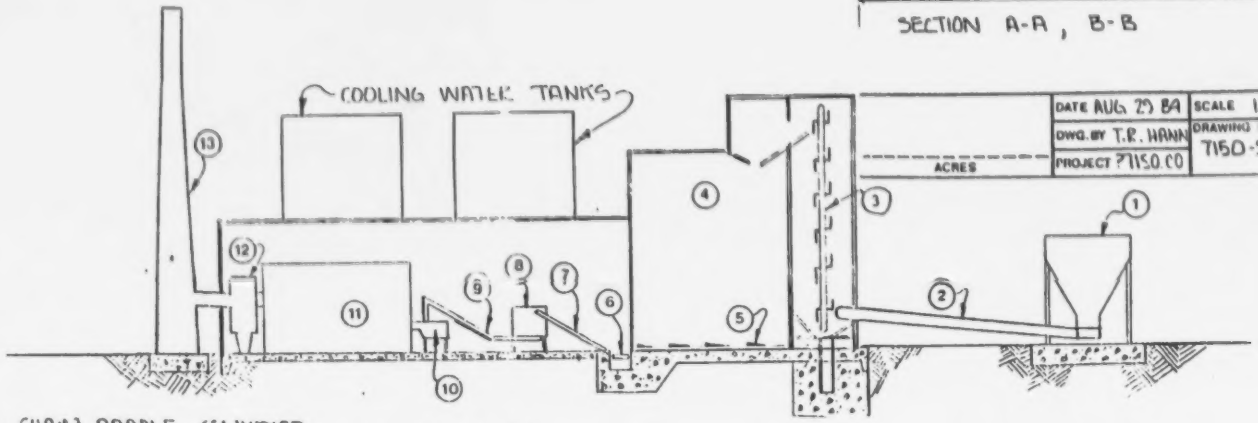

N.T.S. SEE DRAWING 7150-SK-2 FOR SECTIONS A-A, B-B.

ACRES

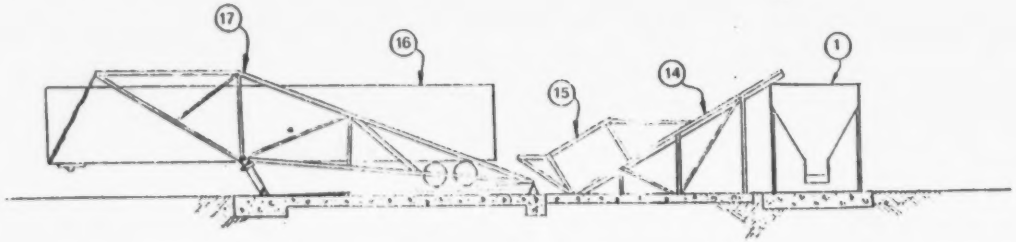
HYDRO DIESEL GENERATING STATION
RODDICKTON NEWFOUNDLAND

SECTION A-A , B-B

DATE AUG. 29 84 | SCALE 1" = 10'-0"
DWG. BY T.R. HANN | DRAWING NO. 7150-SK-2 | REV. A
ACRES | PROJECT 7150.00




SECTION "A-A"




SECTION "B-B"

(1) TRANSFER HOPPER
(2) PADDLE TYPE CONVEYOR
(3) HIGH SPEED BUCKET
(4) SILO
(5) HYDRAULIC PUSH RODS
(6) PADDLE TYPE CONVEYOR
(7) PADDLE TYPE CONVEYOR
(8) SCREEN
(9) SCREW TYPE CONVEYOR
(10) STOCKER
(11) WOOD CHIP BOILER
(12) GRIT ARRESTOR
(13) STACK
(14) TRI-CHAIN PADDLE CONVEYOR
(15) RECIEVING HOPPER
(16) WOOD CHIP TRAILER
(17) HYDRAULIC TRUCK DUMP

# Appendix E
# Thermodynamic Calculations and Fuel Use

**Calculations**

SUBJECT RODDICKTON TURBINE CYCLE W/DEAERATOR

By RLG Date 1 NOV 84 Project No. P715e

Checked ____ Date ____ Calculation No. ____

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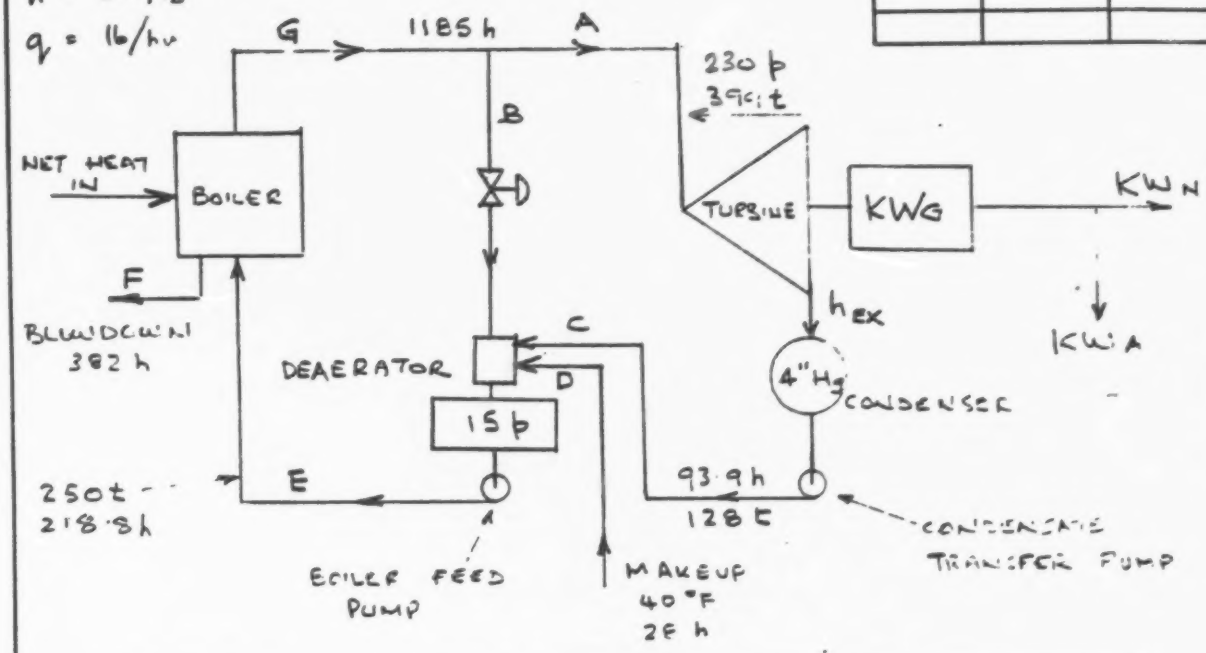
| | | |
| | | |
| | | |

p = psig
t = °F
h = BTU/lb
q = lb/hr




BLOWDOWN (F) = 0.04 × FEEDWATER (E)

MAKEUP (D) = BLOWDOWN (F)

TURBINE GENERATOR LOSSES = 5%

KWG = GROSS GENERATION

KWA = AUXILIARY POWER = 0.05 × KWG

KWN = NET "SENT OUT" GENERATION = KWG − KWA

$$\text{NET HEAT RATE} = \frac{\text{NET HEAT TO BOILER}}{KW_N \times \text{BOILER EFF'y}} \times 100$$

$$h_{EX} = 1185 - \frac{KWG \times 3413}{A \times 0.95}$$

| KWG | FLUID FLOWS lb/h | | | | | | | NET HEAT TO BOILER BTU/hr X10⁶ |
|---|---|---|---|---|---|---|---|---|
| | A* | B | C | D | E | F | G | |
| 1250 | 22,906 | 3,176 | 22,906 | 1087 | 27,169 | 1087 | 26,082 | 25.38 |
| 1000 | 18,850 | 2,614 | 18850 | 894 | 22,359 | 894 | 21,464 | 20.88 |
| 900 | 16,990 | 2,358 | 16,990 | 806 | 20,154 | 806 | 19,348 | 18.83 |
| 815 | 14,889 | 2,065 | 14,889 | 706 | 17,660 | 706 | 16,954 | 16.50 |
| 500 | 10,439 | 1,448 | 10,439 | 495 | 12,382 | 495 | 11,887 | 11.57 |

| KWG | $KW_A$ | $KW_H$ |
|---|---|---|
| 1250 | 63 | 1187 |
| 1000 | 50 | 950 |
| 900 | 45 | 855 |
| 815 | 41 | 774 |
| 500 | 25 | 475 |

* M. MILLS MEMO OCT. 18, 1984

** NET HEAT IN

$= A(1185 - 218.8) + F(382 - 218.8)$

GROSS (FUEL) HEAT IN = $\frac{\text{NET HEAT IN}}{\text{BOILER EFF'Y}}$

Calculations
SUBJECT RODDICKTON
TURBINE CYCLE W/ DEAERATOR
By RLL Date 1 NOV 84 Project No. 12750
Checked ____ Date ____ Calculation No. ____
Page 2 of 3

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| | | |

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**Calculations**

SUBJECT
RODDICKTON
TURBINE CYCLE W/O DEAERATOR

By RLG Date 1 NOV 84 Project No. P 7150
Checked ____ Date ____ Calculation No. ____
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|---|---|---|
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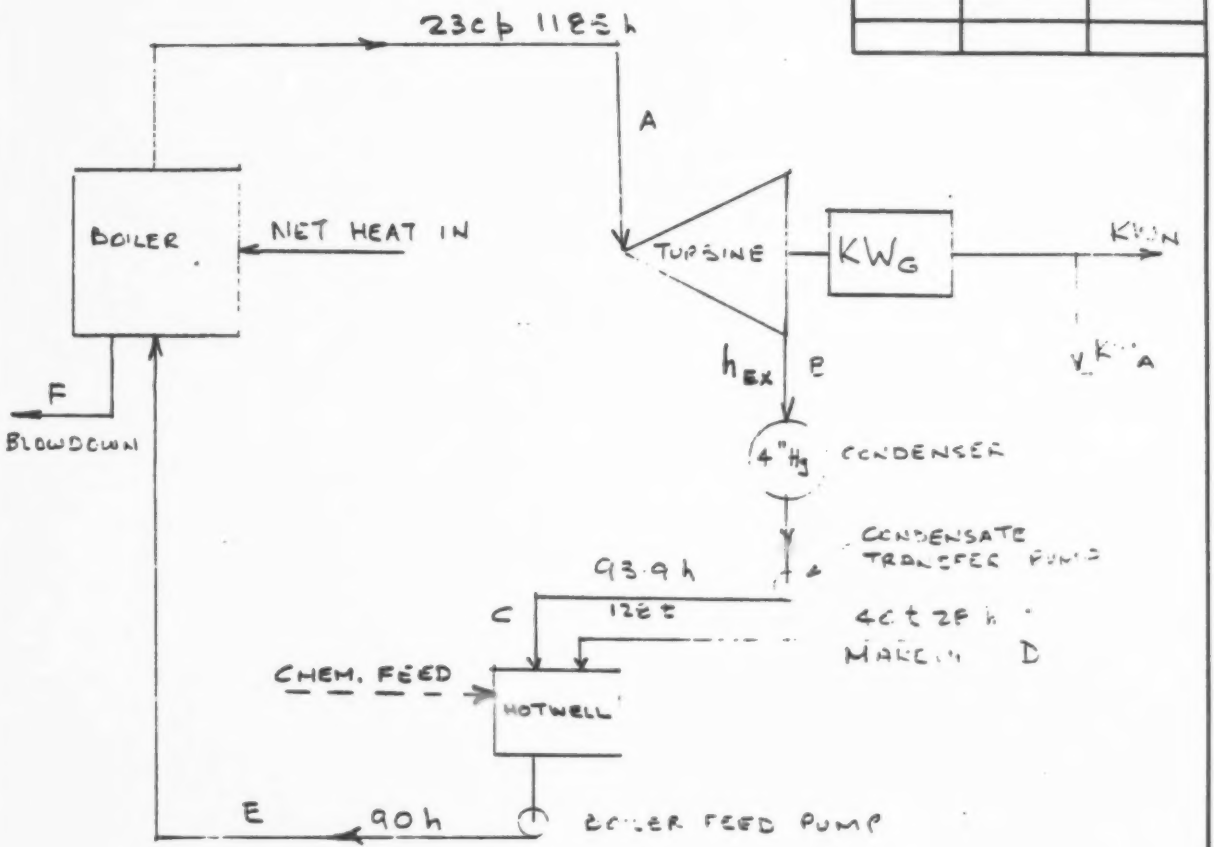


| KWG | FLOWS – lb/hr | | | | | | NET HEAT IN $10^6$ BTU/HR |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | |
| 1250 | 22,906 | 22,906 | 22,906 | 954 | 23,860 | 954 | 25.38 |
| 1000 | 18,850 | 18,850 | 18,850 | 785 | 19,635 | 785 | 20.89 |
| 900 | 16,990 | 16,990 | 16,990 | 708 | 17,698 | 708 | 18.83 |
| 815 | 14,889 | 14,889 | 14,889 | 620 | 15,509 | 620 | 16.50 |
| 500 | 10,493 | 10,493 | 10,493 | 437 | 10,930 | 437 | 11.57 |

**Calculations**

SUBJECT: PODDICKTON FUEL QUANTITIES

By RLG Date 5/11/84 Project No. P7150.00

Checked ____ Date ____ Calculation No. ____

Page 1 of 2

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|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

ASSUME O.D. HEAT CONTENT

IS 8,500 BTU/lb (8% moisture.

AT 45% MOISTURE CONTENT

$$8{,}500 \times \frac{0.55}{0.92} = 5{,}081 \text{ BTU/lb}$$

"as received"

Say 5,000 BTU/lb.

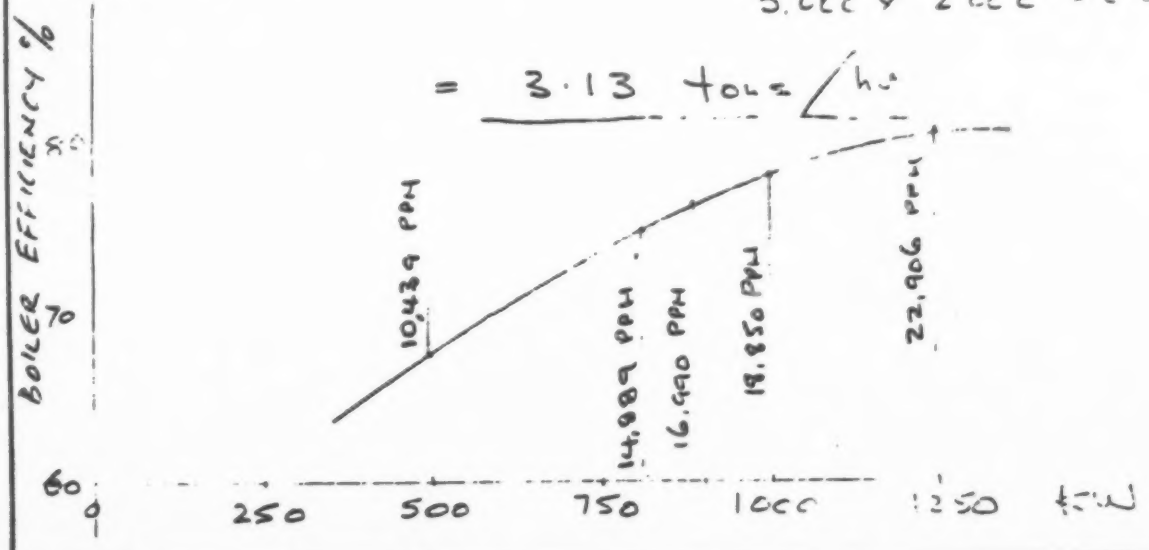
AT 1250 KW, NET HEAT TO STEAM IN BOILER

$$= 25.38 \times 10^6 \text{ BTU/HR}$$

IF BOILER EFFICIENCY IS 81%

FUEL CONSUMPTION IS $\frac{25.38 \times 10^6}{5{,}000 \times 2000 \times 0.81}$

$$= 3.13 \text{ tons/hr}$$



ACRES

**Calculations**

SUBJECT Roderick Ton
FUEL QUANTITIES

By RLC Date 5/11/84 Project No. P715ccc
Checked ____ Date ____ Calculation No. ____
Page 2 of 2

| Rev | By | Checked |
|---|---|---|
| | | |

| TURBINE GENERATOR OUTPUT kW | STEAM FLOW TO TURBINE lb/hr | NET HEAT TO STEAM $10^6$ BTU/hr | BOILER EFFICIENCY % (1) | FUEL HEAT TO STEAM $10^6$ BTU/hr | FUEL WOOD CONSUMPTION (2) T/hr | t/hr |
|---|---|---|---|---|---|---|
| 1250 | 22,906 | 25.38 | 81 | 31.33 | 3.13 | 2.84 |
| 1000 | 18,850 | 20.88 | 78.5 | 26.60 | 2.66 | 2.41 |
| 900 | 16,970 | 18.83 | 76.5 | 24.64 | 2.46 | 2.23 |
| 815 | 14,887 | 16.50 | 75.0 | 22.00 | 2.20 | 2.0 |
| 500 | 10,493 | 11.57 | 67.5 | 17.14 | 1.71 | 1.55 |

(1) 45% moisture content

(2) Green T/hr lb "as received"



60.04.03 Form 1488

## *Table III.* Typical Analyses of Dry Wood * *

| | % by Weight | | | | | | HHV, Btu/Lb | A at Zero Excess Air, Lb/$10^6$ Btu | $CO_2$ at Zero Excess Air, % |
|---|---|---|---|---|---|---|---|---|---|
| | C | $H_2$ | S | $O_2$ | $N_2$ | Ash | | | |
| **Softwoods†** | | | | | | | | | |
| Cedar, white | 48.80 | 6.37 | ... | 44.46 | ... | 0.37 | 8400* | 709 | 20.2 |
| Cypress | 54.98 | 6.54 | ... | 38.08 | ... | 0.40 | 9870* | 711 | 19.5 |
| Fir, Douglas | 52.3 | 6.3 | ... | 40.5 | 0.1 | 0.8 | 9050 | 720 | 19.9 |
| Hemlock, western | 50.4 | 5.8 | 0.1 | 41.4 | 0.1 | 2.2 | 8620 | 706 | 20.4 |
| Pine, pitch | 59.00 | 7.19 | ... | 32.68 | ... | 1.13 | 11320* | 702 | 18.7 |
| white | 52.55 | 6.08 | ... | 41.25 | ... | 0.12 | 8900* | 723 | 20.2 |
| yellow | 52.60 | 7.02 | ... | 40.07 | ... | 0.31 | 9610* | 710 | 19.3 |
| Redwood | 53.5 | 5.9 | ... | 40.3 | 0.1 | 0.2 | 9040* | 722 | 20.2 |
| **Hardwoods†** | | | | | | | | | |
| Ash, white | 49.73 | 6.93 | ... | 43.04 | ... | 0.30 | 8920* | 709 | 19.6 |
| Beech | 51.64 | 6.26 | ... | 41.45 | ... | 0.65 | 8760* | 729 | 20.0 |
| Birch, white | 49.77 | 6.49 | ... | 43.45 | ... | 0.29 | 8650* | 712 | 20.0 |
| Elm | 50.35 | 6.57 | ... | 42.34 | ... | 0.74 | 8810* | 715 | 19.8 |
| Hickory | 49.67 | 6.49 | ... | 43.11 | ... | 0.73 | 8670* | 711 | 20.0 |
| Maple | 50.64 | 6.02 | ... | 41.74 | 0.25 | 1.35 | 8580 | 719 | 20.2 |
| Oak, black | 48.78 | 6.09 | ... | 44.98 | ... | 0.15 | 8180* | 714 | 20.5 |
| red | 49.49 | 6.62 | ... | 43.74 | ... | 0.15 | 8690* | 709 | 19.9 |
| white | 50.44 | 6.59 | ... | 42.73 | ... | 0.24 | 8810* | 715 | 19.8 |
| Poplar | 51.64 | 6.26 | ... | 41.45 | ... | 0.65 | 8920* | 716 | 20.0 |

* Calculated from reported high heating value of kiln-dried wood assumed to contain 8-percent moisture.

†The terms "hard" and "soft" wood, contrary to popular conception, have no reference to the actual hardness of the wood. According to the *Wood Handbook*, prepared by the Forest Products Laboratory of the U. S. Department of Agriculture, hardwoods belong to the botanical group of trees that are broad-leaved whereas softwoods belong to the group that have needle or scalelike leaves, such as evergreens; cypress, larch, and tamarack are exceptions.

* * Table III, page D-17 from: Combustion Fossil Power Systems, Joseph G. Singer, ed. Published by Combustion Engineering Inc., Windsor, Conn. 1981. Reprinted with permission of the publisher.